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Honoré Fabri: A Short Biography

The Jesuit Honoré Fabri was born on 8 April 1608 at Le Grand Abergement, Ain, a small town in eastern France, about eighty kilometers north-east of Lyon.[1] Fabri entered the Jesuit novitiate in Avignon in October 1626 and completed in 1630 his course on Scholastic philosophy (under Claude Boniel) in the *Collège de la Trinité* at Lyon (Fellmann 1971, p. 505). He spent the next two years teaching grammar at the Jesuit College at Roanne. In 1632 he was sent to Rome, to start his course in theology at the *Collegio Romano*, but after one year he was summoned back to Lyon, where he completed (in 1636) his theological training. Meanwhile, in 1635, he was ordained as a priest. Afterwards he was sent to the newly opened Jesuit college at Arles, where he taught logic (1636–1637) and natural philosophy (1637–1638). In Arles he lectured on the circulation of the blood, boasting thirty years later, in his *Tractatus de homine* (1666), that he had publicly taught it before the appearance of Harvey's book (Lukens 1979, pp. 7–8). This vague declaration has been interpreted – by contemporaries and historians alike – as a claim to priority over Harvey, though Fabri himself subsequently argued (as late as 1687) that "at no time did I ever say that the circulation of the blood had been first discovered by me".[2] In 1638–1639 Fabri served as a prefect at the Jesuit College in Aix-en-Provence.

In 1640 Fabri was recalled to the *Collège de la Trinité* at Lyon, where he was promoted to professor of logic and mathematics, as well as to the office of dean. Until 1646 Fabri, "the first of many famous professors produced by the *Collège de la Trinité*" (Vregille 1906, p. 7), taught there logic, metaphysics, astronomy, mathematics, and natural philosophy. In Fellmann's words, "this period was the most brilliant and fruitful of his life; several books that he published later[3] were developed from lectures delivered during this time" (Fellmann 1971, p. 505). It is there that

[1]Lukens 1979, p. 6. Lukens relies on documents contained in the *Archivium Romanum Societatis Iesu* (reproduced as plates I–III, immediately after page 5). Lukens acknowledges that other sources convey different dates or places for Fabri's birth (for example, 1607 or Virieu-le-Grand, Dauphiné), but claims that he "cannot explain these discrepancies" (Lukens 1979, p. 6, n. 1).

[2]Lukens 1979, p. 9. Lukens suggests that Fabri "may have taken the 1639 Lyon edition of *De motu cordis* – or even the 1649 (first) edition of *De circulatione sanguinis* – as the first publication of Harvey's idea" (Lukens 1979, p. 9).

[3]Including his important *Physica* (Fabri 1669–1671).

Fabri and his students – including the future medical doctor Pierre Mousnier (who later edited Fabri's lectures), the mathematician François de Raynaud, and the Jesuits Claude de Chales (philosopher and theologian), Jean Bertet (astronomer) and François de la Chaize (confessor to Louis XIV) – began their correspondence with figures like Pierre Gassendi, René Descartes, Huygens (Constantin and Christiaan) and Marine Mersenne. Fabri's principal book on motion, *Tractatus physicus de motu locali* (Fabri 1646b), as well as his work on logic, *Philosophiae tomus primus* (Fabri 1646a), and his *Metaphysica demonstrativa* (Fabri 1648), were published in Lyon (Lukens 1979, p. 11).

In 1646 Fabri was removed from his teaching office in the *Collège de la Trinité*, under circumstances which are not entirely clear, and sent to a bureaucratic post in Rome. In a letter dated 3 June 1647, the Minime Gabriel Thibaut informed Mersenne that Fabri was "at odds with the fathers of his order (*il est traversé par les Pères de sa Compaignie*), and it is believed that they did everything they could to make him leave, just as they did what they could to withhold the printing of his books".[4] Adrien Baillet, Descartes' biographer, mentions Thibaut's letter, and adds that Fabri's activity in Rome, following his transfer, rehabilitated his position within his order.[5] Neither Thibaut nor Baillet assert that it was specifically holding Cartesian opinions which caused Fabri's superiors to transfer him to Rome, and some historians believe that Fabri became suspected of supporting Descartes only long after the latter died.[6] However, most historians tend to agree that it was "Fabri's aggressive taste for novelties" – whether Cartesian or not – that alarmed his conservative superiors in Lyon and brought about his removal from teaching.[7] In the words of Mordechai Feingold, "the removal of audacious Jesuits from teaching philosophy, as stipulated in the founding documents of the society, became a popular measure against those charged with introducing novel ideas into the classroom" (Feingold 2003, p. 31). It should be emphasized that on 15 February 1643 Fabri took the fourth vow, the special vow of particular obedience to the pope, taken only by select Jesuits (in addition to the three standard vows of poverty, chastity, and obedience),[8] and thus became practically immuned from absolute expulsion from his order. "The complicated procedures required to expel a professed father", explains Robert Bireley, S. J., "made dismissal at the initiative of superiors extremely rare".[9]

[4] Tannery et al. 1945–1988, vol. XV, p. 245.

[5] Baillet 1691, vol. 2, p. 300.

[6] Lukens 1979, p. 15; Sortais 1929, pp. 48–49.

[7] Heilbron 1979, p. 113. See also Feingold 2003, p. 31. Some historians insist that it was specifically Cartesian ideas which led to Fabri's expulsion from Lyon (Vregille 1906, p. 8; Fellmann 1971, p. 505).

[8] Lukens 1979, p. 10.

[9] Bireley 2003, p. 257, n. 90.

Fabri arrived in Rome on 12 September 1646. He became a member of the Minor Vatican Penitentiary, a community of Jesuits responsible for hearing confessions in foreign languages, and was commissioned to hear confessions in French. In 1677 he was appointed rector of the Penitentiary, but three years later he was forced to retire after a quarrel with the Grand Penitentiary.[10] While serving in the Penitentiary, Fabri continued to pursue his scientific interests. Through his acquaintance with the mathematician Michelangelo Ricci he became (in 1660) a corresponding member of the short-lived *Accademia del Cimento* (1657–1667), founded by Prince Leopold de' Medici (Fellmann 1971, p. 506). Fabri produced several important books on current mathematical topics,[11] crusaded in favor of Jesuit's bark (quinine) as a remedy for fever,[12] and embarked on a bitter (and hopeless) controversy against Huygens's discovery of Saturn's rings.[13] Upon his dismissal from the Penitentiary, Fabri retired to the *Gesu* (the Jesuit headquarters in Rome), and was appointed Latin historian of the Society. He died in Rome on 8 March 1688 (Lukens 1979, pp. 30–31).

While in Rome, Fabri flourished – writing all in all more than thirty books, many of them on scientific topics – but nevertheless managed to involve himself in some unpleasant situations. In 1672 he spent almost two months in prison, following the publication of his *Apologeticus doctrinae moralis eiusdem Societatis* (1670), which still appears in the last edition of the *Index librorum prohibitorum* (published in 1948). It is not clear whether it was its vigorous attack on the Jansenists, while defending probabilism,[14] which brought about Fabri's imprisonment,[15] or whether it was an issue of authority which caused this unhappy incident;[16] but it should be emphasized that the reason which is given in some biographical accounts for this affair[17] – namely, Fabri's allegedly soft position towards Copernicanism – is without a doubt incorrect. Fabri claimed that if a proof were ever to be found for the motion of the earth, then the Holy Scriptures should be reinterpreted accordingly, thus only repeating Cardinal Bellarmine's view (from 1616), "which seemed to be relatively common in Jesuit circles" (Finocchiaro 2005, p. 94). Not only was Fabri's scientific activity clearly not responsible for his incarceration, but probably it was thanks to it that Fabri did not stay longer in jail: Prince Leopold, with whom Fabri formed close

[10] Lukens 1979, pp. 17–18. Lukens warns that standard biographies tend to inflate Fabri's position, incorrectly presenting him as "Theologian to the Sacred Apostolic Penitentiary" or even as Grand Penitentiary (ibid., p. 18, n. 36).

[11] On Fabri's mathematical achievements, see Fellmann 1959 and 1992.

[12] On Fabri and the Cinchona bark (from which quinine is produced) see Harris 1998.

[13] Lukens 1979, pp. 19–21. See also Van Helden 1970 and 1973.

[14] Despite the Jesuit General's explicit order from 1669 to refrain from such attacks unless the pope's permission is granted; see Schmaltz 1999, p. 50.

[15] Lukens 1979, pp. 27–28; Heilbron 1979, p. 114.

[16] W. E. Knowles Middleton claims (Middleton 1975, p. 152) that the permission to print this work was given only by Louis XIV, and not by Fabri's Jesuit superiors, thus infuriating ecclesiastical authorities, perhaps even pope Alexander VII himself.

[17] Thorndike 1923–1958, vol. VII, p. 667; Ornstein 1975, pp. 81–82; Fellmann 1971, p. 506; Galluzzi 2001, p. 251, n. 32.

relations during his cooperation with the *Accademia*,[18] had Fabri released within fifty days and restored to his former position (Heilbron 1979, p. 114).

Shortly after his release Fabri found himself again in problematic circumstances. While it is not clear whether it was sympathy to Descartes which caused his dismissal from teaching in 1646, in 1674 Fabri published three apologetic letters (addressed to his fellow Jesuit Ignace-Gaston Pardies) with the explicit purpose of disassociating himself (mainly) from Descartes' philosophy.[19] Interestingly – as will be shown in Part III – in order to defend himself against complaints (received by his superiors) about his loyalty to Descartes, Fabri chose to distort (within this "apology") his own writings from the 1640s, and thus conceal two important Cartesian principles he had borrowed: the conservation of motion and its inherent linearity. Heilbron claims that Fabri (like Pardies himself) "defended himself against charges of Cartesianism by the unpersuasive argument that he rejected Descartes' laws of motion (as did everyone else)".[20] However, as Part III will show, Fabri's line of defense (in 1674) would be more accurately described as simply "deceptive" (rather than as "unpersuasive"): his theory of motion (established in his 1640s' writings) was in fact much more Cartesian than either Fabri himself, or modern historians, would usually be prepared to admit, in 1674 or anytime afterwards.

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[18]A decade before Fabri's imprisonment Leopold gave him, as a special token of appreciation, "some of the delicate glass apparatus for which the *Accademia* was and is so celebrated" (Heilbron 1979, p. 196).

[19]Fabri 1674, pp. 5–6. See also Blum 1999, pp. 235, 243.

[20]Heilbron 1979, p. 37, n. 23.

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Introduction

During his lifetime, Honoré Fabri was a somewhat controversial figure, though well-known – belonging to the mainstream of mid-seventeenth century science. He was favorably mentioned in the *Philosophical Transactions*, both as a free-thinker who “hath emancipated himself considerably from the Scholastick way of Philosophing (*sic*)” and “dares maintain, that the Vegetative and Sensitive Souls are not *Substantial* Forms”,[1] and as a moderate Jesuit, who was willing to declare that in case a proof for the earth’s motion is found “the Church will not at all scruple to declare, that these places are to be understood in a figurative and improper sense”.[2] Gottfried Leibniz had great respect for Fabri, especially in the field of mathematics,[3] but also in natural philosophy: for example, Leibniz expressed his sympathy towards Fabri’s criticism of René Descartes’ physics.[4] Leibniz’s criticism of Fabri’s philosophy, which grew stronger over the years (for example, he blamed the Jesuit for lack of rigor in his demonstrations) casts doubts on the sincerity of the German philosopher, while declaring Fabri – in a letter addressed to the Jesuit – to have achieved for himself, by “many and highly erudite works”, a place “among the best authors of our time”.[5] However, we have no reason to suspect Leibniz of exaggeration (or

[1]“Review: An Account of Some Books... *Tractatus duo; quorum prior est de plantis et de generatione animalium; posterior, de homine* by Honorati Fabri”, *Philosophical Transactions of the Royal Society of London*, 1:18 (Oct. 1666), pp. 325–327 (written apparently by Henry Oldenburg). Fabri’s rejection of substantial forms, except that of humans (i.e. the soul) is discussed in Section 19.4 below.

[2]“A Further Account, Touching Signor Campani’s Book and Performances about Optick-Glasses”, *Philosophical Transactions of the Royal Society of London*, 1:4 (June 1665), p. 75 (written apparently also by Henry Oldenburg). The quote is a translation from Fabri [pseud. Eustachio Divini] 1661, p. 49.

[3]In particular, Leibniz appreciated (and was, as he himself admitted, influenced by) Fabri’s method of the quadrature of the cycloid; Hofmann 1974, p. 51, n. 26. See also Fellmann 1971, pp. 505–506.

[4]Leibniz 2006, p. 237. Fabri’s rejection of Descartes’ reduction of matter to extension (a reduction leading to the denial of void) is discussed in Part IV, Section 19.1 below.

[5]“Dudum enim plurimis et doctissimis in omni prope scientiarum genere monumentis id effecisti, ut inter primos nostri temporis autores habeare”; Leibniz to Fabri, 17 May 1677, in Leibniz 1987, vol. 2, p. 122.

polite flattery) when he refers to him, in his *New Essays on Human Understanding*, as "one of the ablest members of his order".[6]

Christiaan Huygens "acknowledged Fabri's work on compound pendula as being a pioneer contribution" (Lukens 1979, p. 31), and Marin Mersenne deemed Fabri "a veritable giant in science" (Heilbron 1979, p. 195). Henry Oldenburg, while expressing (ill placed) contempt towards a fellow Jesuit of Fabri,[7] nevertheless included Fabri himself among the "most Ingenious and famous Philosophers and Mathematicians".[8] Pierre Gassendi and even Robert Boyle also expressed appreciation of Fabri.[9] G. A. Borelli seemed to harbor an intense animosity towards Fabri, referring (in a letter to prince Leopold) to the Jesuit's "cranky brain" and claiming (having read Fabri's *Dialogi physici*) that he talked "a lot of nonsense as usual" (Bertoloni Meli 1998, p. 393); yet the same Borelli – "a man most difficult to please" – also admitted (in another letter to Leopold) that "the keenness of this priest's mind is truly admirable, as well as the great learning, frankness, and conviction with which he treats innumerable difficult and recondite matters" (Heilbron 1979, p. 196). Isaac Newton, who first learned of Grimaldi's important discovery of diffraction from Fabri's *Dialogi physici* (1669),[10] nevertheless regarded Fabri as merely a second-rate mathematician, and was consequently extremely (though hardly untypically) offended when Leibniz – in good faith, not intending any disrespect – compared his English rival to Fabri.[11]

By the middle of the twentieth century, almost nothing remained from Fabri's original good reputation. Fabri, as other Jesuits, "came to be excluded from the general histories of philosophy written by Protestants in the eighteenth and early nineteenth century, and as a result remained excluded from histories of philosophy for the next 150 or so years" (Blackwell 1995, p. 53). Modern historians forgot – or overlooked – the compliments bestowed on him by so many (and so important) contemporaries, and usually regarded him as no more than a senior representative of the malevolent order whose crafty machinations led to the downfall of Galileo. At their worst, historians either saw him as merely someone who "represented the views of the Inquisition",[12] or claimed that that he (and all his fellow Jesuits) can be understood only in light of Loyola's thirteenth rule, to "believe that the white I see is black, if the hierarchical Church so defines it" (Ashworth 2002, p. 133). Somewhat less extreme accounts regarded Fabri as a staunch defender of the old

[6]Leibniz 1996, p. 498. This compliment is conveyed while again criticizing Fabri, this time concerning a theological issue.

[7]The secretary of the Royal Society "greeted with scorn" Ignace-Gaston Pardies' "respectful and merited criticism of Newton's theory of colours in 1672"; Feingold 2003, p. 3.

[8]In a letter to John Winthrop, March 1 1668/9, quoted in Blackwell 1995, pp. 58–59.

[9]Galluzzi 2001, p. 252, n. 37; Lukens 1979, p. 12; Heilbron 1979, p. 204.

[10]Lukens 1979, p. 31; see also Hall 1990.

[11]See Section 3.1 below on this unfortunate misunderstanding which fueled the famous quarrel between Newton and Leibniz.

[12]Shapley 1949, p. 17. Shapley describes, in this paper, Fabri's objection (which he subsequently withdrew) to Huygen's discovery of Saturn's rings.

philosophy who employed cunning tactics to attack the pioneers of the New Science (i.e. Galileo, Descartes and their followers). According to Lynn Thorndike, Fabri "attempted to meet developing modern science on its own ground, to fight against it with its own weapons, or, to change the figure, to accost it with diplomatic courtesy and seeming friendliness, to yield a few minor points, and to try to outwit it on more important issues".[13] Less hostile accounts refrained from ascribing to Fabri such a devious scheme, but continued to depict his theory as entirely conflicting with the New Science. Esther Caruso, for example, quotes Fabri's impressive compliment towards Galileo – that he "wonderfully and with almost divine sharpness of genius led local motion to where no mortal had led it before" – but sees fit to stress that notwithstanding Fabri's courtesy, the analysis of motion he himself proposed was strictly Aristotelian and anti-Galilean.[14]

There is no doubt a strong connection between the poor opinion historians tended to form concerning Fabri (especially his theory of motion) and his decision to turn the old concept of impetus into the cornerstone of physics. In his influential work *Etudes Galiléennes* (1939), Alexandre Koyré harshly criticized this medieval concept – which since the fourteenth century denoted the force (or quality) which maintains the motion of a projectile – and deemed it a "muddled" notion, the desertion of which (by Galileo) eventually led to classical (i.e. post-Newtonian) physics. In particular, Koyré saw in the concept of impetus an insurmountable hindrance to the modern principle of inertia, which arises from the fact that impetus is an efficient cause of motion.[15] Koyré himself most probably never addressed the philosophy of Fabri, but other historians of science did express their opinions on Fabri's philosophy of motion, and were no doubt highly influenced by Koyré's firm judgment concerning impetus vis-à-vis classical physics in general, and inertia in particular.

Annelise Maier was the first to apply Koyré's basic insight to Fabri's philosophy of motion. She claimed – in the spirit of Koyré's thesis – that Fabri's concept of impetus was completely alien to the new "mechanics of inertia". While in the fourteenth century, explained Maier in *Zwei Grundprobleme*... (1951), the theory of impetus clashed with the Aristotelian traditional view and gradually gained acceptance, by the seventeenth century it became part of the "dogma", and was used by Fabri (among others) to combat the new inertial physics of Galileo and Descartes (Maier 1951, pp. 312–313). Following Maier, Alfred Boehm (1965) and Maurice Clavelin (1974) expressed views in the same vein, i.e. declaring the total incompatibility between Fabri's impetus and the idea of inertia, and advocating the identity between Fabri's concept of impetus and Buridan's (see Chapter 12 below).

Stillman Drake, in several papers published in the 1970s, and his student David Lukens, who dedicated a PhD dissertation to Fabri (1979), contributed further to the depiction of Fabri as a staunch enemy of the New Science. The title of Lukens's dissertation – "An Aristotelian Response to Galileo: Honoré Fabri, S.J. (1608–1688) on

[13] Thorndike 1923–1958, vol. VII, p. 665.

[14] Caruso 1987, pp. 107–108. Fabri's quoted praise of Galileo will be discussed in Chapter 6 below.

[15] This subject is extensively discussed in Chapter 13 below.

the Causal Analysis of Motion" – contains the essence of their view. The branding of Fabri's physics as an "Aristotelian response to Galileo" indicates Fabri's loyalty to traditional physics and hostility towards the New Science, while referring to Fabri's view as a "causal analysis of motion" hints that his philosophy of motion is entirely alien to the concept of inertia, according to which straight motion with a constant velocity does not need any cause. Sure enough, both Drake and Lukens deny any affinity between Fabri's concept of impetus and the idea of inertia. Furthermore, not only do they ascribe to Fabri unconditional loyalty to the scholastic traditional concept of impetus, but they also regard his mathematical analysis of natural motion (the most debated aspect of Fabri's philosophy of motion) as merely an elaborate version of a view formulated in the fourteenth century. Drake and Lukens insistently claim that Fabri's discrete analysis of free fall was already contained (or implicit) in the views of John Buridan and Albert of Saxony, thus distorting (as I will show in this book) not only Fabri's theory, but also the views of these two late medieval philosophers.

Some historians have attacked Fabri's philosophy of motion from another important angle – the perspective of void space and the possibility of motion through it. Michael J. Gorman named Fabri among the Jesuit philosophers who allegedly formed an "anti-vacuist" front which supported Aristotle's arguments against the void (in book IV of the *Physics*) while contrasting Torricelli's contention to have created a vacuum in his famous experiment.[16] Pietro Redondi, depicting the vacuum as "a new, frightening breach through which the heresy of Galilean physics could again pour in like a flood" (Redondi 1987, p. 292), described the fight against it as "a great battle, into which anti-Galilean strategy threw the best front-line troops of the Society's official science" (ibid., p. 294). Redondi, like Gorman, saw in Fabri's rejection of Torricelli's contention a typical Jesuit expression of loyalty to "Aristotelian categories", but also connected it to the "necessity of maintaining the hylomorphic perspective because of the theological necessity of safeguarding the Scholastic interpretation of the Eucharistic Dogma" (ibid., p. 295). Marcus Hellyer, relying on Gorman and Redondi – clearly without consulting Fabri's works themselves – included Fabri among the Jesuits who "published texts opposing any possibility of the vacuum and indicating the dangers posed to the Eucharist by such corpuscular physics" (Hellyer 2005, p. 104).

Occasionally a less biased attitude towards Fabri's philosophy can be found, especially concerning subjects other than philosophy of motion: Emil A Fellman expresses appreciation towards Fabri's mathematical achievements;[17] John L. Heilbron describes Fabri's participation in the activity of the *Accademia del Cimento* and praises Fabri for having discovered that electrical attraction is mutual;[18] Dennis Des Chenne identifies in Fabri's chemical theory "some of the marks of the

[16] Gorman 1994, pp. 14–17, 21–22.

[17] See "Honoré Fabri: A Short Biography" above, Note 11, as well as Section 3.1 below.

[18] Heilbron 1971, pp. 46–47; 1979, pp. 198–202.

novator".[19] Regarding Fabri's philosophy of motion, Gideon Freudenthal emphasizes Descartes' influence on Fabri, in the context of the parallelogram rule (of forces) and the problematic concept of *determinatio*;[20] Domenico Bertoloni Meli outlines Fabri's interesting theory concerning the orbits of Jupiter's satellites, in which he employs Galileo's parabolas;[21] Lukens himself, despite his overall view of Fabri as an enemy of Galileo and a mere copycat of Buridan, describes Fabri's "very successful application of the impetus theory" to "the study of the oscillations of rigid bodies" (Lukens 1979, p. 247); Lukens also expresses a reserved amount of appreciation towards Fabri's theory of collision, deeming it as generally "incorrect" (ibid., p. 244) but admitting that "Fabri is closer to actual experience than Descartes is when a small ball hits a larger one".[22] Palmerino, who studied Fabri's theory of free fall (Palmerino 2003), displays a more balanced approach than previous discussions concerning Fabri's view on this subject. Following A. G. Molland, who asserted that Fabri's "discrete approach arose not from his being an impetus theorist but from his being of the seventeenth century" (Molland 1982, p. 48), she no longer feels obligated to "attach" Fabri – at all cost – to medieval physics, and is willing to regard him as a legitimate representative of his own century, rather than an "advocate of Lost Causes" (Lukens 1979, p. 26). However, as will be shown in Chapter 11, even Palmerino is still not free from the strong historiographic tendency to regard Fabri as first and foremost Galileo's adversary.

The purpose of my book is not to deal with minor (or limited) aspects of Fabri's theory of motion, but to refute once and for all the opinion which since Maier's account has dominated the prevailing view concerning the essentials of Fabri's philosophy of motion, and propose an alternative account. Maier's decisive assertion against any possibility of compatibility between Fabri's concept of impetus and the notion of inertia (eagerly adopted by Drake and Lukens) was recently repeated by Paolo Galluzzi, who stated that "the notion of conservation of movement" was "not taken into account in Fabri's theory of motion".[23] It is also evident in Ugo Baldini's judgment (referring to all Jesuit philosophers, not Fabri alone) that "even after 1640 they constantly repeated the traditional analyses of motion: the majority accepted impetus, but they considered it as a self-consuming entity which cannot bring forth motion of indefinite or infinite duration, even in a vacuum in the total absence of external forces" (Baldini 2004, p. 106). I intend to show that Fabri's concept of impetus – indeed central to his theory of motion – should not by any means be

[19]Though he still regards Fabri as all in all "a sturdy defender of the Jesuit version of Thomist Aristotelianism"; Des Chene 2001, pp. 363, 378.

[20]Freudenthal 2000, pp. 132–135; see Section 15.1 below.

[21]This "monstrous but highly suggestive theory" (in the words of Bertoloni Meli), appears in Fabri 1665; Bertoloni Meli 1998, pp. 393–395.

[22]The issue of collisions will only be touched upon in this book (see Section 15.1). Lukens's judgment concerning the general incorrectness of Fabri's theory of collisions is in itself correct, but Fabri's attempt to follow Descartes' pioneering effort to analyze collisions – one of the earliest endeavors of this sort among contemporaries – deserves closer attention in the future.

[23]Galluzzi 2001, p. 267, n. 93.

seen as a backward device serving to *fight* the New Science, but should rather be deemed a sophisticated tool for *assimilating* it. In particular, regarding (like Maier and her many followers) Fabri's concept of impetus as alien to the classical notion of inertia is simply wrong. It will be shown that Fabri carefully redefined the concept of impetus, as well as the causal connection between impetus and motion, so as to be able to smoothly assimilate the basic idea behind "inertia", i.e. the important concept of Conservation of Rectilinear Motion (hereafter designated CRM), which can be defined in the following way: "an object once moved in a certain direction, and henceforth affected by no other factor, will continue *ad infinitum* in its motion along that very direction with uniform velocity". Fabri, eager to adopt the principle of CRM – which even before appearing in Descartes' *Principia* (1644) was widespread among pioneers of the New Science – achieved this by defining impetus as a *formal* (rather than *efficient*) cause of motion, thus evading the (valid) argument Koyré would raise (three centuries after Fabri) against the compatibility of impetus and inertia.[24] Furthermore, in order to ensure the linearity of the motion conserved,[25] Fabri followed Giovanni Battista Benedetti, against the medieval impetus tradition, in limiting the action of impetus to straight lines. Moreover, although Fabri – unlike Descartes before him and Newton after him – did not define CRM as a law of nature, nevertheless it was an integral part of what could be described as his "inertial framework", which was not only expressed by CRM, but also by the analysis of natural phenomena in vacuum, by support for Galileo's claim concerning the universal velocity of fall in the void, and by the abstraction of air resistance from the analysis of motion. It is even possible to connect Fabri's advanced mathematical thought, which regards curves as entities formed by moving points (always along "local" tangents), with his CRM principle and the view of circular motions as "impeded" straight lines.

Contrary to Hellyer, Fabri's view is far from "opposing any possibility of the vacuum". Rather, Fabri claims that the (full) universe is immersed in an infinite vacuum, and passionately defends the scientific validity of the concept of void, both by adopting Suárez's notion of "abstract" space (*ubicatio*),[26] and by severely criticizing Descartes' anti-vacuist reduction of matter to extension.[27] Contrary to Redondi, Fabri's theory of the Eucharist (to be extensively discussed in this book) did not entail any reservation whatsoever concerning void or motion in it; rather – as will be shown – it provided the Jesuit with a wonderful opportunity to glorify the quality of impetus, thus probably rendering the anti-Aristotelian phenomenon

[24] Regarding impetus as a formal cause of motion allows impetus not to be exhausted while causing motion, while Koyré assumed that every impetus theorist regarded impetus as an efficient cause, which is necessarily gradually consumed while causing motion and thus can never be "inertial" (even in the absence of hindrances).

[25] Against Beeckman's and Gassendi's "generic" (i.e. circular as well as linear) conservation of motion, or Galileo's debatable view on this matter (see beginning of Chapter 14 below).

[26] Which, unlike Aristotle's old concept of *locus*, allows for the existence and motion of bodies in empty space.

[27] This is the criticism which earned the appreciation of Leibniz mentioned above.

of eternal motion (caused by an unfailing impetus) more plausible among Jesuit circles. Contrary to Gorman, Fabri, rather than supporting Aristotle's arguments against the void, formulated – in an appendix (to his *Metaphysica demonstrativa*) entitled *De Vacuo* – a fierce attack against the fourth book of the *Physics*; an attack in which he refuted, explicitly following Galileo, two of Aristotle's alleged paradoxes resulting from the assumption of void (i.e. the alleged "instantaneity" of motion and absence of a possible mover) and deemed two other "paradoxes" (CRM and universal velocity of fall in the void) to be perfectly correct physical principles.

In this book I shall adopt Rivka Feldhay's "dialogical" approach, which (unlike Maier, Drake and their followers) does not assume an "automatic dichotomy" between the New Science (especially Galileo) and Jesuit natural philosophy. I shall closely examine the way Fabri applied his newly defined concept of impetus, as well as the "inertial framework" he borrowed from the New Science, within his analysis of the two most important branches of terrestrial physics of his generation: natural motion (i.e. free fall) and projectile motion. It will be shown that concerning free fall Fabri succeeded in assimilating Galileo's theory, though employing a different kind of a mathematical analysis. While Galileo used a continuous analysis, involving innovative and ingenious ideas – which were nevertheless still unacceptable, not only by Jesuits like Fabri but also by *novatores* like Descartes – Fabri embarked on a discrete analysis (which evaded many of the problems Galileo encountered), ultimately proving that this analysis perfectly converges to Galileo's (under the assumption of infinitesimal instants). It will be shown that *pace* Drake and Lukens, Fabri's discrete analysis – exemplifying his "inertial framework" (including CRM, analysis of motion in the void, and abstraction from air resistance) – cannot be considered to be contained (or even implicit) within fourteenth century impetus theories, to which this "inertial framework" was completely alien. Furthermore, Fabri's severe attack on Aristotle's theory of natural motion, which includes the abolition of levity as a basic property of bodies (recognizing only "absolute gravity"), as well as the Jesuit's rejection of Aristotle's contentions that weight affects the speed of fall and that the medium is responsible for natural acceleration, indicate the huge influence of Galileo on Fabri, hitherto underestimated by historians.

Regarding projectile motion, Fabri was less successful (from the point of view of classical mechanics). Although again adopting an "inertial framework", repeating his belief in CRM and analyzing this phenomenon in vacuum (thereby consciously abstracting from air resistance), Fabri rejects the important principle of superposition, together with the Galilean solution of parabolas, supplying instead an original alternative method of explaining the projectile's trajectory. Fabri's proposed explanation, based on the Aristotelian notion that nothing in nature is "in vain" (*frustra*), was deemed by him a solution that "saves the phenomena" – i.e. accounts better (qualitatively, not quantitatively) for the observed curve of a projectile. However, not only is Fabri's solution entirely incorrect, but it reveals a serious limitation of Fabri's inertial thinking and exemplifies his anti-Classical ideal of science, according to which physics should be restricted to "sensible" (i.e. actually observed) phenomena.

In short, there is no doubt that Fabri should not be seen as a physicist belonging to the rank of Galileo and Descartes. He certainly did not contribute any great idea, or discovery, concerning the theory of motion, and specifically his account of projectile motion (though not his explanation of falling bodies) should indeed be seen (in retrospect) as a regression, rather than progression, vis-à-vis the groundbreaking theory of Galileo and his followers. However, Fabri – an ardent supporter of CRM within a general "inertial framework", devising an alternative to Galileo's law of fall but in effect proving their equivalence – should certainly be seen as an *assimilator* of the New Science, rather than its enemy (Maier); as a philosopher astonishingly open to new and anti-scholastic ideas, rather than "a sturdy defender of the Jesuit version of Thomist Aristotelianism" (Des Chene); as a resourceful and enthusiastic integrator of New Science essentials, rather than a cynic and a hypocrite who was willing to convey "diplomatic courtesy and seeming friendliness" to rising modern science and "to yield a few minor points" only in order to "outwit it on more important issues" (Thorndike).

Part I, "Basic Concepts", begins by initially presenting the unique importance Fabri ascribes, within his general physical scheme, to the concept of impetus. The following chapter describes Fabri's deductive (*more geomterico*) methodology concerning physics and the texts which are the most important in the context of this book: *Tractatus physicus de motu locali* (Fabri 1646b), *Metaphysica demonstrativa* (Fabri 1648), and – to a lesser extent – *Philosophiae tomus primus* (Fabri 1646a) and *Physica*, *id est*, *scientia rerum corporearum*, *in decem tractatus distributa* (Fabri 1669–1671). Part I afterwards analyzes the essentials of Fabri's philosophy of motion, i.e. his basic ideas concerning motion, impetus (the cause of motion, the cornerstone of his physics), and the carefully defined connection he establishes between them.

Chapter 3 presents Fabri's definition of motion – "the transition of a mobile from one place to another by a continuous flux" – and then interprets the meaning of the term *fluxus*. Despite its medieval origins (in the context of the famous ontological debate between *fluxus formae* and *forma fluens*), Fabri's concept of *fluxus* seems rather connected to his "mechanical" mathematical philosophy, which regards curves as a result of moving points. Although this "mechanical" mathematical tradition – common to Fabri and many contemporaries, and adopted also by Newton – does not entail a similarity between Fabri's *fluxus* and Newton's much more sophisticated "fluxion", nevertheless it points to an important connection between Fabri's mathematical and physical thinking (the results of which are discussed in Part III). This chapter discusses also Fabri's somewhat complicated conception of motion as a *resultans*, *ut relatio*, or to be more exact – a relation of simultaneity (*relatio simultatis*) that connects the mobile, its *termini* (*a quo* and *ad quem*) and the impetus residing in it. Finally, Fabri's treatment (or rather, lack of treatment) of Aristotle's definition of motion (*motus est actus entis in potentia*, *prout in potentia*) is discussed.

Chapter 4 analyzes Fabri's definition of impetus: "a quality exacting (i.e. compelling) motion, or flow of place, of its subject; or [the quality] which is the proximate cause of the motion of that mobile in which it is, i.e. in that way in which it can be a cause of motion". In order to fully understand this definition, this chapter begins by explaining Fabri's theory of qualities, which describes impetus as a non-modal accident (defined as an accident which can exist, by a miracle, outside its subject); according to Fabri, only impetus and heat are non-modal accidents, while all the rest are modal (i.e. they cannot exist outside their subjects, not even by a miracle). It then delineates the special causal relation between impetus and motion: motion, not being a full-fledged *ens*, is not produced (*producitur*) by impetus, but only exacted, or compelled (*exigitur*) by it; consequently, impetus is a formal, rather than efficient, cause of motion, while motion is a "formal effect" (i.e. goal) of impetus. This qualification, at first glance no more than a standard scholastic commentary concerning the worn-out subject of the ontology of motion, in fact serves Fabri to formulate an unprecedented unifying theory of impetus: as a formal (and thus necessarily inner and "natural") cause for any kind of motion (violent as well as natural), his concept of impetus blurs the dichotomy between natural and violent motion significantly more than the medieval concept of impetus (which had emphasized the "violent" aspect of projectile motion). Fabri achieves this (relative) unity by ascribing (against scholastic tradition) purposefulness to impetus, while emphasizing quality rather than substance – thus conveying an anti-Aristotelian view which attributes a "desire" to an accident.[28] An unhindered impetus, claims Fabri accordingly, "would without doubt rejoice in its goal", i.e. in motion. Furthermore, as Fabri explains, formal causality (unlike efficient causality) does not entail the exhaustion of the cause by the mere act of causing, and thus impetus (in the absence of hindrances) is conserved, allowing the adoption of a relatively advanced philosophy of motion (to be further discussed in Part III).

The remainder of Part I surveys traditional scholastic attitudes towards motion, impetus and the connection between them. It focuses first on Thomas Aquinas's important interpretation of Aristotle, concerning the "formal" principle of natural motion, that might have influenced Fabri's notion of impetus as a formal cause. It then discusses two of the most influential fourteenth century impetus theorists: Franciscus of Marchia and Jean Buridan. This discussion delineates their proposed theories of a projectile, examining the extent of their similarity to Fabri's theory, in terms of causality between impetus and motion and the emphasis on quality at the expense of substance.

Part II discusses Fabri's theory of natural motion, part and parcel of the extensive debate inaugurated by Galileo's crucial discoveries concerning this issue (a debate labeled by Paolo Galluzzi the "Second Galilean Affair"). This part shows the overwhelming influence Galileo had on Fabri in this matter, and how he assimilated Galileo's essentials regarding free fall, although in his own terms.

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[28] Aristotle insists that a form "cannot desire" (see Section 4.3 below). Fabri does not achieve of course full unity between natural and violent motion, for he still distinguishes between natural and violent impetus. For the two kinds of natural impetus Fabri identifies see Chapter 8 below, especially Note 18.

Part II first describes Fabri's harsh criticism towards Aristotle's philosophy of natural motion, expressed by a total rejection of levity as an absolute property of matter (thus reducing natural motion to free fall alone); by invalidating the rules Aristotle had formulated concerning falling bodies and directly blaming him for failing to examine accelerated motion; and finally by ascribing natural motion to an inner cause (rather than Aristotle's external one). Afterwards Fabri's own conception is outlined: having shown that natural motion demands an inner cause, Fabri establishes impetus as this cause. The adoption of Galileo's Archimedean-style "infrastructure", which discards levity and allows for motion in the void, enables Fabri to develop – using the "legitimate" concept of impetus – a discrete analysis of free fall (in the void), a mirror image of Galileo's continuous analysis. Accordingly, Fabri accepts not only all Galileo's experimental results, but also the Galilean key principle of the simple proportionality between velocity and time ($v \propto t$) and works out the "natural numbers" rule of falling bodies: in each successive (equal) amount of time a falling body passes a distance which is one unit bigger than its immediate predecessor, i.e. according to the simple series 1, 2, 3, 4, 5... Now Fabri successfully proves that assuming time instants small enough, his law truly converges to Galileo's famous "odd numbers" rule (which claims that the distances grow according to the series 1, 3, 5, 7, 9...). In this way Fabri was able to advocate, rather than his own cumbersome discrete analysis, Galileo's proportion $\mathrm{s} \propto \mathrm{t}^2$ (which is correct only according to a continuous analysis), thus completing the assimilation of Galileo's theory of free fall.

Special attention is given to the details of Fabri's discrete analysis. While it is based on Fabri's conception of a "physical instant", a basically discrete term (contrary to Galileo's infinitesimal – i.e. a "mathematical" – instant, rejected by Fabri), it is important to realize that this physical instant nevertheless has a divisible, and therefore continuous, aspect. According to Fabri, a physical instant, while being indivisible "actually intrinsically", is also divisible "potentially extrinsically", a fact which allows us (according to Fabri) to find a smaller instant than any given one. This characterization, which at first glance seems as no more than a scholastic obscurity, in fact gives credence to Fabri's proof of the convergence of his natural numbers rule to Galileo's odd numbers rule.[29] Another issue discussed in this context is the question whether such a discrete analysis of free fall does indeed appear (or is implicit) – as Stillman Drake and David Lukens contend – in the theories of the two fourteenth century protagonists of impetus, Jean Buridan and Albert of Saxony. It is shown that such cannot be the case, and that although Fabri's attitude is not original, its source does not lie in the fourteenth century, but in the early seventeenth century (e.g. Isaac Beeckman).

Part II also closely analyzes Fabri's "assimilation strategies", in order to understand how Fabri managed to prove the equivalence of his view (endorsing the medieval concept of impetus and a discrete analysis) to Galileo's revolutionary

[29] The proof relies on an everlasting division of a given unit of time, which is possible due to the "potential extrinsic" divisibility of an instant (see appendix below).

conception, which renounces any causal analysis of natural motion and employs a continuous outlook. It is shown that Fabri's basic conception of time, seemingly a seventeenth century invention (accompanied by a Beeckman-style discrete mathematical analysis, which is indeed novel), is actually rather conservative in its basic philosophical outlook, and amounts to an application of the dichotomy Aristotle used to characterize the infinite (existing potentially, but not actually) to the term "physical instant" (potentially divisible, actually indivisible), thus permitting the convergence of a discrete analysis to a continuous one. Regarding the issue of impetus, having "proved" it is the cause of natural motion (thus being able to present his theory as "legitimate" in scholastic terms), Fabri cunningly neutralizes it as a factor which has any effect on the rate of fall, using – again – principles which are *prima facie* scholastic obscurities: basing himself on the distinction between influencing *ad intra* and *ad extra*, and on the formal causality between impetus and motion, he argues in favor of Galileo's principle of the universal rate of fall (in the void), i.e. the inherent independence of the velocity of a falling body from any physical property (impetus included). Thus Fabri can embark on a purely kinematic analysis, entirely free of any dynamical consideration, which is ultimately proven to be equivalent to Galileo's analysis.

However, it must be emphasized that assimilation does not amount to unreserved acceptance. While adopting many essentials of Galileo's theory of free fall, Fabri could not accept neither the Pisan's conscious decision to disregard the cause of natural motion, nor his "continuous" mathematical treatment, which implied problematic assumptions concerning the structure of the continuum (this is why Fabri employed impetus, his alleged cause of natural motion, and chose to develop a discrete analysis). Fabri adopted Galileo's key proportion $v \propto t$, but rejected his mathematical analysis, along with the contention that a falling body which achieves a given velocity necessarily passes through infinite smaller ones. However, this rejection does not render Fabri an "enemy" of Galileo, nor does it testify (like some historians argue) to any struggle between the "modern" Galileo and the "medieval" Fabri: Galileo's assumptions, no matter how trivial in our modern eyes, were highly controversial in the middle of the seventeenth century, and were flatly rejected not only by Fabri, but also by exemplary *novatores* like Descartes, Gassendi, Roberval and Mersenne.

Part III discusses the details of Fabri's adoption of CRM, which is especially (though not exclusively) relevant in the context of violent motion. Its opening chapter explains why in regard to Fabri and his contemporaries the term CRM (rather then "inertia") should be used, and then describes the opinions of historians – who unanimously proclaim the opposition between CRM (or inertia) and Fabri's theory of motion. It then outlines Fabri's conception of impetus as an entity requiring a non-material factor which conserves it – a factor which is ultimately identified as God. Thus Fabri formulates an opinion similar to that of Descartes, who held God's immutability responsible for the conservation of the quantity of motion. Accordingly, Fabri adopts Descartes' insight that the question which should be raised in the context of projectiles is not their persistence (which is caused by the conservation of impetus, guaranteed by the continuous preserving action of

God), but their retardation. Fabri finally declares (in *De impetu*, the first book of his *Tractatus physicus de motu locali*) that "impetus is conserved as long as nothing exacts (or compels) its destruction" (theorem 147).

The next chapter explains why in Fabri's case the conservation of impetus strictly entails conservation of motion, while in the theories of the fourteenth century protagonists of impetus (e.g. Jean Buridan and Albert of Saxony) it did not. The reason is Fabri's full acceptance of the possibility of motion devoid of any resistance, that entails such an anti-Aristotelian consequence as the possibility of perpetual motion which is straight, violent and sublunary. Fabri's view concerning the possibility and scientific validity of void (*pace* Aristotle and Descartes) is described, as well as his "thought experiment" (outlined in the appendix *De vacuo* of his *Mataphysica demonstrativa*) in which he depicts a stone inertially moving in a universe emptied (except for this moving stone) by God. Special attention is given to Fabri's subsequent sharp attack on Aristotle's refutation of the possibility of vacuum (in *Physics*, book IV). During this attack Fabri – explicitly relying on Galileo – deems two of the "paradoxes", formulated by Aristotle to prove the "absurdity" of the concept of void, to be valid physical principles, and not paradoxes at all: 1. the universality of velocity of fall in the void, which entails the constant falling speed of all bodies, regardless of their shape or weight (assuming the absence of any material medium); 2. the infinity of straight and uniform motion which a body (once moved) acquires in a totally unresisting environment, i.e. the principle of CRM.

The following chapter discusses the inherent linearity of Fabri's impetus, which entails specifically conservation of rectilinear motion rather than of both linear and circular motion (as, for example, Beeckman and Gassendi maintained). Fabri, following Descartes, employs the old scholastic notion of *determinatio* to describe the necessary basic linearity of impetus (and consequently motion): "an impetus", he declares in *De impetu*, "must be determined (*determinatus*) along a certain line of motion" (theorem 112). Fabri's use of the concept of *determinatio*, within his analysis of reflection from totally elastic planes, is subsequently described. Finally, Fabri's view concerning circular motion is outlined: as a direct consequence of his (relatively) modern conception of motion as inherently linear, Fabri regards circular motion as arising from an impeded straight motion, and accordingly observes that a stone tied to a sling will proceed along a straight line tangential to the circular original trajectory if the rope suddenly breaks.

The last chapter of Part III outlines Fabri's theory of projectiles, the rather peculiar synthesis between some New Science principles and old notions, in which Fabri adheres to basic CRM but rejects Galileo's principle of superposition, in favor of a scholastic-style "*frustra*" mechanism which is responsible for the destruction of violent impetus. This chapter shows that while adhering to his basic "inertial framework", and devising a theory that purports to "save the phenomena",[30] Fabri failed

[30]As explained in Section 16.2 below, Fabri's solution might resemble reality only when very strong air resistance is involved.

to develop a useful theory of projectiles which could be regarded as an advance vis-à-vis the pioneering theory of Galileo and his disciples.

Part IV, "Fabri and the Eucharist", discusses Fabri's intensive use of the impetus concept within his explanation of the Eucharist, the subject which originally inspired the birth of this concept (in its specific physical meaning) in the fourteenth century.[31] Its first chapter presents the two major problems of the Eucharist, which are nothing but the two sides of the same coin: the Accidents problem (i.e. the mystery concerning the persistence of the observable properties of bread and wine after Transubstantiation[32]), and the Real Presence problem (the problem of explaining the manner in which Christ exists in the host after the consecration, even though we still perceive bread and wine). The second chapter of Part IV describes Fabri's proposed solution (in his *Metaphysica*) for the Accidents problem, which recommends the quality of natural innate impetus as the significant accident (i.e. property) of bread and wine which survives Transubstantiation and "carries" the remaining observable accidents. Fabri first argues that only the non-modal (i.e. "absolute") accidents – (innate) impetus and (primary) heat – remain "extended impenetrably" following the consecration, and thus can "carry" all the remaining properties. He then claims that natural innate impetus, which he identifies with absolute gravity (or heaviness, *gravitas*), necessarily exists (unlike heat) in every chunk of matter whatsoever, and therefore it is the real quality which indeed solves the Accidents problem and "saves the phenomena". In Fabri's words, God "supplies this accident with the power to perform the function of substance", which was converted to Christ's substance during Transubstantiation. This chapter also discusses the problematic aspect – from the point of view of the Eucharist – of Fabri's belief in extended indivisibles, which indeed feature in Fabri's theory of the Eucharist, and have been explicitly banned (because of this sacrament) by the Jesuit authorities.

The third chapter of Part IV outlines Fabri's handling of the Real Presence problem, the more difficult issue among the two, since while the Accidents problem does not defy the senses (for we do observe bread and wine even after the consecration), the Real Presence problem does. In his *Physica*, Fabri labors to neutralize this mind-boggling problem from any physical aspect, and he in effect transfers Real Presence from physics to metaphysics. This chapter describes how Fabri achieves this goal: he first describes "body" as something which "exacts" (i.e. requires, or compels) impenetrability, explicitly refraining from directly identifying body with impenetrability because of the issue of Real Presence; he then defines "internal quantity" also as a property which exacts impenetrability, concluding that the terms "body" and "internal quantity" are in effect identical. Having characterized "internal quantity" from the outset as a metaphysical (rather than physical) property, Fabri eventually concludes that although *proprie & metaphysice* Transubstantiation transforms the

[31] Franciscus of Marchia had used the close forerunner of impetus, *vis derelicta*, as a possible way of explaining the persistence of Christ in the host following the sacrament.

[32] Namely, the process dictated by the Catholic authorities, by which the substance of the host is fully and absolutely converted to that of Christ.

substance of the host to that of Christ, *aequivalenter physice* its "internal quantity" (namely, body) remains the same – thus in effect sterilizing the physical facet of Transubstantiation. Fabri's concept of "internal quantity" was commonplace among Jesuits, who were significantly influenced by the Nominalist criticism towards Thomas's solution to the Accidents problem, which held the accident of quantity to be the surviving property (of bread and wine) that "carries" the remaining sensible attributes following the consecration. Fabri, who explicitly attacks Thomas's solution of quantity while recommending his own impetus for this purpose, can thus be regarded as cunningly employing a typical Jesuit custom (to divide quantity to "internal" and "external", and thus assimilate Nominalist criticism while retaining a Thomistic appearance) within his general aim both to praise his concept of impetus and to purge physics of the unsolvable Real Presence problem.

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Contents

Part I
Basic Concepts

Chapter 1
Introduction: The Primacy of Impetus

In the beginning of his major work on motion, *Tractatus physicus de motu locali* (1646), Fabri has set himself an ambitious goal – the reduction of "not only motion itself but also the whole of physics" to the concept of impetus:

> We begin this treatise on local motion with the impetus itself, on the knowledge of which certainly all this issue depends; for since impetus is the immediate cause of motion, as we shall prove at length below; and since a thing cannot be known as a reasoned fact (*propter quid*)[1] unless its reason is known; there cannot be any doubt but that a discussion about impetus should come first, so that afterwards the properties of motion itself will be proved by its cause; indeed I would dare say that not only motion itself but also the whole of physics depends on the knowledge of impetus alone.[2]

The well-known concept of impetus has ancient origins but was developed mainly in the fourteenth century in order to explain projectile motion and natural acceleration of falling bodies, the two phenomena which standard Aristotelian physics had found difficult to cope with. Aristotle, loyal to his general dictum – that "everything that is in motion is moved by something" – held the medium responsible both for projectile motion[3] and for natural acceleration,[4] but his theory gradually accumulated many opponents. For many generations, philosophers criticized Aristotle's solution, proposing instead an idea that was still in keeping with Aristotle's dictum: a motive "force" (*vis*, or *virtus*), or a quality (*qualitas*), that resides in the projected (or falling) object and continues its motion (or acceleration). In the fourteenth century, this concept was introduced to the Latin West

[1] See Wallace 1972–1974, vol. 1, pp. 29–47 (as well as Chapter 6 below) for the difference between an explanation *quod* (or *quia*), "of the fact," and a demonstration *propter quid* ("of the reasoned fact").

[2] "Tractatum hunc de motu locali ab ipso impetu auspicamur, ex cuius profecto cognitione tota res ista dependet; cum enim impetus sit causa immediata motus, ut fuse demonstrabimus infra; & cum propter quid sit res cognosci non possit, nisi eius causa cognoscatur; dubium esse non potest, quin praemittenda sit tractatio illa, quae est de impetu, ut deinde affectiones ipsius motus per causam eiusdem demonstrentur; immo ausim dicere ex unius impetus cognitione, non modo motum ipsum, verum etiam totam rem physicam pendere" (Fabri 1646, lib. 1, p. 1).

[3] *Physics* [Aristotle 1930], 8, 10, 266b25–267a12.

[4] *On the Heavens* [Aristotle 1953], 3, 2, 301b17–30.

M. Elazar, *Honoré Fabri and the Concept of Impetus: A Bridge Between Conceptual Frameworks*, Boston Studies in the Philosophy of Science 288,
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as Franciscus of Marchia's *virtus derelicta* and was further crystallized into John Buridan's "impetus".[5] In the following centuries the concept of impetus prospered and became a major scholastic doctrine. The sixteenth century seems to be the "Golden Age" of impetus,[6] but the New Science (e.g., the physics of Galileo and Descartes) clearly went "very different ways" – it discarded once and for all Aristotle's dictum, and relied less on impetus, though the latter did not cease to play a role within physical theories: as late as 1696, impetus was still used (by English members of the Royal Society) to explain several mechanical phenomena.[7] In any case, the notion of impetus still prevailing in the seventeenth century was generally no longer the old principle which had replaced Aristotle's medium, while still conforming to the old dictum. From the sixteenth century onwards, impetus was in the process of losing its function as a *cause* of motion, and becoming solely an *effect* of motion, comparable to the concept of momentum in modern physics, i.e. serving as a measure of motion rather than its cause.[8] Furthermore, within this process it was gradually forfeiting any ontological significance, and thus changing from a basic physical principle to a narrow technical term which was used as an ad hoc solution to certain specific problems.[9]

Contrary to the general late degradation of impetus, Fabri certainly considers it – in the passage quoted above – as a definite cause of motion, and at any rate as much more than a narrow technical term. Later we shall see that he regards impetus as a "quality", i.e. an entity belonging to one of the nine "accidental" categories of Aristotle's, and as the key (along with the quality "heat") to understanding not only local motion, but nature in its entirety.[10] As for "local motion" itself – i.e. change of place, the subject matter of *Tractatus physicus de motu locali* – it is of course only one of the three types of motion (*κίνησίς*) defined by Aristotle, the other two being alteration, i.e. change of quality, and augmentation and diminution, change of quantity.[11]

Aristotle himself – in the beginning of his major physical treatise –formulated a "physical creed" of his own: "Nature", Aristotle says, "is a source or cause of being moved and of being at rest in that to which it belongs primarily". Because "nature has been defined as a 'principle of motion and change' ", he adds somewhat later, we

[5]The influential theories of Marchia and Buridan are discussed below.

[6]See Clagett 1959, pp. 629–671 for a general survey of the success of impetus not only in Western Europe, but also throughout Germany and in Eastern Europe.

[7]Sarnowsky 2006, pp. 141, 142.

[8]Clagett 1959, p. 681. It should be noted though that Buridan, who indeed sees impetus as the cause of motion, does not clearly distinguish between impetus as a cause and impetus as an effect (see Section 9.2 below).

[9]Sarnowsky 2006, pp. 141, 144.

[10]On Fabri's theory of qualities, see Section 4.1 below.

[11]*Physics* [Aristotle 1930], 5, 1, 225b8. Change of substance, i.e. generation or corruption, belongs to the wider term *μεταβολή* (change) but does not qualify as *κίνησίς* (*Physics* [Aristotle 1930], 5, 1, 225a; see also Note 4, written by the translators R.P. Hardie and R.K. Gaye, to *Physics*, 3, 1, 201a7).

must "see that we understand the meaning of 'motion'; for if it were unknown, the meaning of 'nature' too would be unknown". Soon afterwards Aristotle formulates his famous definition of change, i.e. "motion" in its broad sense, which throughout history has received many interpretations (and also not a few criticisms): "The fulfillment of what exists potentially, in so far as it exists potentially, is motion".[12]

Particularly interesting is the interpretation of Thomas Aquinas to Aristotle's definition, stated also (and perhaps better known) by the phrase "the actualization of the potential as such". As William Wallace observes, Aquinas – in his commentary to the *Physics* – explicitly regards this definition as a *formal* definition of motion, i.e. the definition which "gives the formal cause of *motus*" (Wallace 1979, p. 34). Fabri, as will soon be shown, also saw his concept of *impetus* as the formal cause of (local) motion. It could be worthwhile then, even in this early stage, to briefly – and in very general terms – compare these two general conceptions of nature, each choosing its own principle as a definition, "essence", or "formal cause" of motion. The Stagirite, on the one hand, focuses on the first and foremost category – "substance" – and supplies a "definition of motion", i.e. a means to understand every possible change (or absence of change) that can occur to "that to which it belongs primarily", i.e. to any given substance affected by it; "change", after all, is not a category existing by itself. On the other hand Fabri concentrates on Aristotle's second category (one of the nine "accidental" categories) – "quality", and claims that "the whole of physics" can actually be explained in the terms of this category. Also, whereas Aristotle regards change as a very broad concept, containing not "local motion" alone, Fabri ignores in the *Tractatus* the other types of *motus*; the title of his book already points to this fact, while the passage just quoted makes it clear that according to Fabri the understanding of local motion alone (through its formal cause, i.e. impetus) is the key for understanding nature in its fullness. This change of outlook, which might be described as a "shift from substance to quality", will be soon shown to be a significant ingredient of Fabri's physical thought.

Naturally, the "background" of Fabri's physical thought – at least its "traditional" aspect – is not the theory of Aristotle himself, nor even Aquinas's commentary, but rather those constituting the vast field of "Late Peripatetics", the seventeenth century successors of the Aristotelian frame of mind, which since the thirteenth century dominated western thought in general and the university establishment in particular. It seems worth mentioning – within this preliminary discussion – two important distinctions concerning motion that Allan Gabbey proposed in order to differentiate between the "mechanists" (or *novatores*) of the early seventeenth century and the contemporary "Late Peripatetics", and then seeing where Fabri stands in relation to them.

1. The total primacy of local motion over the other three types of change, explains Gabbey, was already prevalent among both camps. However, while for the Peripatetics its primacy still consisted in "being the *sine qua non* of all other

[12] *Physics* [Aristotle 1930], 2, 1, 192b22 & 3, 1, 200b10–14, 201a10.

categories of Peripatetic motion", for the "mechanists" it rather consisted "in its being the explanatory *sine qua non* of *all* physical phenomena" (Gabbey 1998, p. 649). If we rely – at least tentatively, for now – on Fabri's ambitious claim stated above, we may conclude that his approach occupies some middle ground between the (late) Peripatetic and the mechanistic attitudes: not only does Fabri single out local motion as the most important type of motion, he actually ignores (in his *Tractatus*) all the other types altogether; furthermore, in his metaphysical work (*Metaphysica demonstrativa*) Fabri chooses to deal with "*motus localis abstractus*" rather than generic "*motus abstractus*".[13] However, he does not see local motion itself as a *sine qua non*, but rather its *cause* – impetus.

2. Gabbey also remarks that among the mechanists

> there was general agreement on the redundancy of the traditional distinction between natural and violent motion in favor of the principle that all motions, whatever their Peripatetic categorizations, are the natural effects of motive forces, and conversely, that all forces, whatever their origin, act *secundum naturam* to cause motions and rest (Gabbey 1998, p. 650).

As we shall see, Fabri distinguished between "violent impetus", which is impressed from outside, and "natural impetus", i.e. the impetus which is responsible for downward motion or pressure (when such motion is inhibited), and thus could be said to preserve the old natural/violent distinction. However, the very use of the concept "impetus" implies a tendency to analyze motions of all kinds – natural and violent alike – using the same concept: even before Buridan, Islamic philosophers tried to account both for projectile motion and free fall using the concept of *mail*, the Arab predecessor of impetus (Clagett 1959, pp. 510–514). Furthermore, this part will show Fabri's important contribution to this medieval inclination, towards a conception not all that different from Gabbey's description of the "mechanist" view: by emphasizing the *natural* aspect of impetus – even violent impetus – Fabri integrated, more than any of his predecessors, the two types of motion, despite retaining the distinction itself. This is intimately connected to Fabri's emphasis on quality (impetus), rather than substance: a moving substance, according to Fabri, is totally controlled by an inhering impetus – which by its nature (and as an intrinsic goal, as will be explained soon), *formally* causes this substance to move; the substance might move "naturally" or "violently", but the working of the impetus – i.e. the fact that it causes motion – is explicitly seen by Fabri as an internal and natural process. In any case, due to the fact that Fabri nevertheless continues to employ the old concept of impetus, and does not abandon altogether the violent/natural distinction, we should conclude (in the meantime) that in this respect also Fabri's conception of motion lies somewhere between those we generally consider as "late Peripatetics" (not an easily defined category by itself) and the mechanical *novatores* who brought about Classical Mechanics.

[13] The twelfth book of *Metaphysica demonstrativa* is entitled "De motu locali abstracto", i.e. it focuses on local motion. It is termed "abstract" because Fabri considers here motion not of corporeal objects alone, but also of angels etc.

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Chapter 2
Methodology and Main Texts

Naturally, before we may form a learned opinion on Fabri's theory of motion, we must analyze it much deeper than the level on which his general "scheme" or "creed" (to reduce all phenomena to impetus) stands. Fabri's conception of impetus is outlined in detail in the first book of *Tractatus physicus de motu locali* (1646), "On impetus", and this will be the main source of the analysis proposed in this first part. Fabri's *Tractatus*, his central treatise on local motion, is one of the three books which purport (according to their titles) to be excerpts from Fabri's lectures given at Lyon, assembled by his student Pierre Mousnier. The first of these books, *Philosophiae tomus primus* (1646) deals with logic, and the last one, *Metaphysica demonstrtativa* (1648) with metaphysics. As Lukens remarks, "the books as printed were taken to be Fabri's opinions, and he never repudiated any of them" (Lukens 1979, p. 112). Furthermore, in later writings Fabri refers to them as his own.[1]

Fabri's works abandon the traditional disputational form of *quaestiones*, and are formulated *more geometrico*, constructed more or less according to the "deductive" guidelines set by Aristotle in his *Posterior Analytics*. At the beginning of this methodological work Aristotle explains that every "way of argument proceeds from pre-existent knowledge", and that "mathematical sciences and all other speculative disciplines are acquired in this way".[2] He emphasizes that scientific knowledge necessarily involves knowing the causes of facts:

> We suppose ourselves to possess unqualified scientific knowledge of a thing, as opposed to knowing it in the accidental way in which the sophist knows, when we think that we know the cause on which the fact depends, as the cause of that fact and of no other, and, further, that the fact could not be other than it is.[3]

Furthermore, according to the *Posterior Analytics* "demonstrative", i.e. "scientific", knowledge must base itself on premises that have to be "true, primary, immediate, better known than and prior to the conclusion, which is further related to them

[1] For example, Fabri thus refers to the *Tractatus physicus de motu locali* in a letter to Leibniz from 1671 – Gerhardt 1960–1961, vol. 4, p. 243 – and to the *Metaphysica demonstrtativa* in his published letters to Pardies (Fabri 1674, p. 14).

[2] *Posterior Analytics* [Aristotle 1928], 1, 1, 71a1–5.

[3] *Posterior Analytics* [Aristotle 1928], 1, 2, 71b8–12.

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as effect to cause".[4] Fabri indeed constructs his treatise of motion in accordance with this "geometrized" model, not unlike Newton's *Principia Mathematica*, published 41 years after Fabri's *Tractatus*. Fabri opens each of the ten books of his *Tractatus* with definitions, hypotheses and axioms, to be followed by theorems, which are developed on the basis of those three kinds of "premises".

Definitions, explains Fabri (following Aristotle), do not entail the existence of the entity defined. For example, after defining the concept "impetus", Fabri emphasizes that in the same way that a geometer defines a circle without committing himself to the existence of a "perfect circle", so does he – a physicist – define impetus without affirming its existence (a task he leaves for the theorems soon to follow).[5]

Hypotheses, according to Fabri, serve also as starting points to the deductive process of obtaining theorems: this is in keeping with the *Posterior Analytics*, in which "hypotheses" are referred to as basic scientific premisses, along with postulates and definitions.[6] But in Fabri's account, the hypotheses themselves are drawn from certain "experiments", or experience. Fabri's general idea of "experiment" (*experimentum*) or "experience" (*experientia*) is very conservative, or "naïve" in our standards, and as Peter Dear observes Fabri "still means by it the Aristotelian concept of 'experience' " (Dear 1995, p. 138). This is how Fabri defines the term "*experimentum*", in his *Philosophiae tomus primum* (1646):

> A physical experiment (*experimentum*) is some sensible effect, physically certain and evident – that is, such that it cannot fail (except by miracle). For example, at one time I see a stone move, at another I see it not move; I see the same thing with a sphere of lead and of wood; I feel the greater blow of a stone falling from a greater height, etc.[7]

Fabri's view of *experimentum* is reminiscent of the Ockhamist notion of "intuitive cognition", i.e. evident knowledge which is derived from direct experience.[8] At any rate, from these "experiments", or "experiences", Fabri derives physical hypotheses, and they are always qualitative (and not quantitative) assertions – e.g. "falling bodies accelerate",[9] or "a projected body, even after it is separated from the

[4] *Posterior Analytics* [Aristotle 1928], 1, 2, 71b21.

[5] "…nec enim affirmo in hac definitione dari impetum; sed definio tantum quid sit impetus; qui revera aliud non est, si est: quippe id tantum concipio, cum impetum appello; sive sit, sive non sit, ne quis forte initio statim mihi litem intendat; quemadmodum definit circulum Geometra; licet non asserat dari perfectum circulum; ita Physicus definit impetum, quamvis non affirmet dari impetum; quod tamen in sexto Theoremate demonstrabimus" (Fabri 1646b, lib. 1, def 3, p. 2); cf. *Posterior Analytics* [Aristotle 1928], 2, 10, 93b28–37.

[6] *Posterior Analytics* [Aristotle 1928], 1, 10.

[7] "Experimentum physicum, est effectus aliquis sensibilis, certus & evidens Physice, id est, ita ut citra miraculum fallere non possit, v. g. video laipdem modo moveri, modo non moveri; idem video in globo plumbeo, ligneo; sentio maiorem ictum lapidis ex maiore altitudine cadentis, &c". (Fabri 1646a, lib. 3, cap. 4, art. 3, p. 88; quoted in Dear 1995, p. 139; I have slightly altered Dear's translation).

[8] Adams 1987, vol. 1, pp. 501–506.

[9] Fabri 1646a, lib. 3, cap. 4, art. 3, p. 88.

motive force, still moves; I appeal to the eyes of everyone as witnesses".[10] It must be added that as Dear explains,

> Fabri's use of the word "hypothesis" is not intended to refer to a statement or group of statements that are conjectural, awaiting test through the empirical investigation of their consequences. Instead, he uses it to mean "fundamental statement", that is, a statement suitable to stand as a premise at the beginning of logical demonstration. A specifically *physical* hypothesis, furthermore, provides the relevant cause in a physical demonstration.[11]

Fabri concludes with a "most certain rule": "a physical hypothesis follows only from a certain experiment with which it has a necessary connection".[12] In the third part we shall see how such an "hypothesis" led Fabri to an erroneous (but nevertheless very interesting) derivation of the curve describing an horizontal projectile.

Following the hypotheses come the axioms. An axiom, explains Fabri, is nothing but a "universal proposition deduced from all the physical hypotheses".[13] "Hence" – continues Fabri, echoing Aristotle's claim that the premises should be "better known than and prior to the conclusion" – "there is no more truth and certitude in the axioms than the truth of the hypotheses; and no more truth in these than the truth of the experiments, which is certain, except for a miracle, for the senses cannot be deceived when they are well applied". Fabri concludes that "the truth of the hypotheses and axioms is certain. But surely this certitude is physical, not geometrical, nor are the demonstrations of physics more certain than the axioms of physics by which they are demonstrated".[14] As Dear explains, "physical certainty" took, in contemporary classification, a middle position between "metaphysical" (or "geometrical") certainty, i.e. the highest grade of certainty, and "moral" certainty – the lowest grade.[15]

In the first book of the *Tractatus* Fabri supplies 15 axioms, out of which the first seven "seem at least partly metaphysical, but they belong to physics in such a way that without them many physical properties cannot be explained and demonstrated".[16] For example, the first of these "partly metaphysical" axioms claims that "contradictions cannot simultaneously exist or not exist". The latter half of the

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[10]"Hypothesis VI: Corpus proiectum etiam a potentia motrice seiunctum adhuc movetur. Oculos omnium testes appello" (Fabri 1646b, lib. 1, hyp. 6, p. 5).

[11]Dear's emphasis. Dear 1995, p. 140; Fabri 1646a, lib. 3, cap. 4, art. 3, p. 88.

[12]Fabri 1646a, lib. 3, cap. 4, art. 3, p. 89; Lukens 1979, p. 117; his translation.

[13]"...ut multa experimenta faciunt hyhpothesin, sic multae hypotheses faciunt axioma, quo nomine intelligimus propositionem universalem, quae ex omnibus hypothesibus physicis deducitur" (Fabri 1646a, lib. 3, cap. 4, art. 4, p. 90).

[14]Fabri 1646a, lib. 3, cap. 4, art. 4, p. 90; Lukens 1979, p. 118 (his translation).

[15]Dear 1995, p. 139, n. 47.

[16]"Observabis septem praemissa Axiomata, licet metaphysica saltem aliqua ex parte esse videantur, ita pertinere ad Physicam, ut plurimae physicae affectiones sine illis explicari, & demonstrari non possint" (Fabri 1646b, lib. 1, ax. 7, scholium, p. 8).

axioms include axioms which pertain more specifically to physics, and most of them concern causality – e.g. (axiom 9) "a cause must exist in order to act immediately".[17]

The most important part of the *Tractatus* consists of theorems, developed on the basis of the abovementioned definitions, hypotheses and axioms. In the second book of the *Tractatus* Fabri explains that his "method", i.e. his way of doing physics, consists in converting hypotheses, i.e. facts known *quod sit* only, to theorems – facts known *propter quid sit* ("reasoned facts"), facts that are causally explained and therefore constitute real *scientia*.[18] For example, Fabri uses impetus to explain and substantiate as a physical fact the observed phenomenon (which itself is only a hypothesis) of the gradual increase of velocity during free fall.[19]

Fabri's metaphysical treatise, *Metaphysica demonstrativa*, *sive scientia rationum universalium* (1648), can be seen as an investigation of universal concepts, i.e. concepts which according to Fabri are abstracted both from corporeal and incorporeal objects, for example entity, substance, accident, relation, place, time, extension and motion.[20] Unlike the *Tractatus*, it does not contain any hypotheses, but uses definitions and axioms as premises. Thus the axioms appearing in Fabri's *Metaphysica* can never be "drawn from hypotheses", i.e. be based on experience, and must be "theoretical", thus determined *apriori*.[21] Another difference is that the *Metaphysica* employs *propositiones* instead of the *Theoremata* used in the *Tractatus*, though both have of course exactly the same meaning and also the same relation to the abovementioned premises; it should also be emphasized that unlike the *Tractatus*, Fabri's *Metaphysica* deals with all standard four types of change.

Another text important to this book is Fabri's *Physica, id est, scientia rerum corporearum, in decem tractatus distributa* (1669). This extensive work is also constructed *more geometrico*, and employs, like the *Metaphysica*, propositions (and not theorems), though like the *Tractatus* it contains also hypotheses (in addition to axioms). The *Physica* includes ten treatises: the first four deal with "sensible states of bodies" (*De statibus corporum sensibilibus*), the next one with "principles of a natural body, its generation and its corruption, and the four elements", the two following treatises with mixtures, another one with heavenly bodies and the last two with "plants, animals and man".[22] The first part of Fabri's *Physica*, *De statibus corporum sensibilibus*, which concentrates on the basic properties of bodies (such as impenetrability and gravity, i.e. "innate impetus") is the part mainly consulted within this book, and despite the late date of the book's publication (1669), there can be no doubt that at least this part was written many years before, possibly

[17] Fabri 1646b, ax. 1, p. 5, ax. 9, p. 9.

[18] As William Wallace explains, the precursors of modern science "associated the Latin term *scientia* with causal science. *Scientia est cognitio per causas*" (Wallace 1972–1974, vol. 1, p. 6).

[19] Fabri 1646b, lib. 2, th. 16, p. 84.

[20] Lukens 1979, pp. 112–113; Fabri 1646a, lib. 2, cap. 1, art. 2, p. 3. See also Blum 1999, p. 241.

[21] For example, the first axiom of book 2 repeats the axiom mentioned above from the *Tractatus*, and asserts: "contradictoria simul esse, vel non esse, non possunt" (Fabri 1648, lib. 2, ax. 1, p. 33).

[22] Fabri 1669–1671, "auctor lectori", par. 1.

even already in the late 1640s.[23] Ugo Baldini regards Fabri's *Physica* as the "first non-Aristotelian scheme" of Jesuit textbooks, and observes that in this work "Fabri completely replaced the old questions by a purely empirical classification of the properties of bodies, which was extraneous to the Aristotelian order" (Baldini 1999, p. 269). Charles B. Schmitt also recognizes the difference between Fabri's physical work and standard Aristotelian textbooks, and notes that in the *Physica* "both the mathematical and the observational aspects of the new approach to nature have a place, and the old *quaestio* form is all but abandoned for something more closely approaching the mathematical textbooks which were to follow, such as Newton's *Principia*" (Schmitt 1984, p. 225).

Interestingly, by identifying Fabri's *Physica* as a new, perhaps even revolutionary, kind of textbook, both Baldini and Schmitt ignored in their papers Fabri's three books written (supposedly by Mousnier) more than 20 years earlier, formulated in the same "deductive" spirit. Naturally, the most important text for this book is not the *Physica* (which is constructed according to empirical categories of phenomena, and has no specialized and systematic section on motion per se[24]), but one of these three books, namely the work which analyzes the concept of impetus and applies it to the study of motion: *Tractatus physicus de motu locali*. Before consulting the text of the *Tractatus physicus de motu locali*, it is worth examining its table of contents (Fig. 2.1).

As we can see, the first book is dedicated to the concept of impetus, and Part I will be mainly based on it. The titles of the second and the third book, "on natural motion downward" and "on violent motion upwards", apparently convey a standard scholastic outlook. As mentioned before Fabri relegates (within his theoretical explanation) the dichotomy natural/violent from motion to impetus, though it is clear (already from the table of contents) that he does not abandon the old vocabulary. I have already mentioned above (and shall elaborately explain below) Fabri's emphasis of the *natural* aspect of impetus, as the formal cause of motion in general (i.e. including violent motion), which serves to blur the distinction violent/natural motion. But apart from that, even within the table of contents, we can see that although this distinction appears, it does not occupy a very prominent place: only two of the books contain any trace of it; the other books either have no connection whatsoever to this distinction, or discuss types of motion that are natural and violent simultaneously (book 4 deals with motion along inclined planes, and book 8 with pendulums). Naturally, even if Fabri had originally meant to stay loyal to Peripatetic notions and

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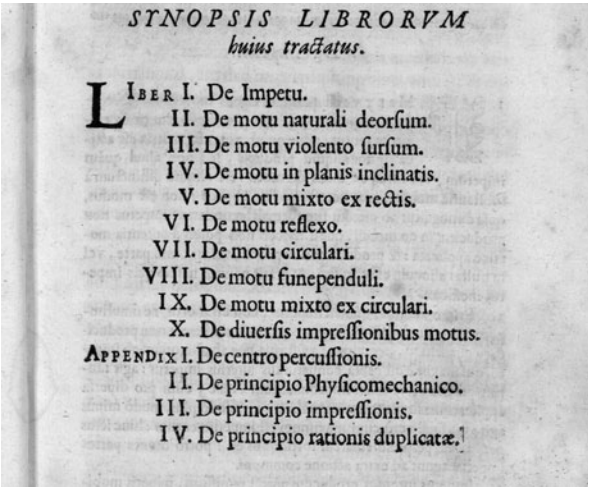
[23]Theorem 73 of the second book of the *Tractatus* refers the reader to the future *Tomus de statibus corporum sensibilibus* (Fabri 1646b, lib. 2, th. 73, p. 115). Furthermore, in the abovementioned letter to Leibniz (written in 1671) Fabri refers jointly to his *Physica* and his *Tractatus physicus* (Gerhardt 1960–1961, p. 243), hinting that his basic physical line of thought did not substantially change over those years.

[24]See also Baldini 1999, p. 269, n. 84. Fabri does discuss in this book, of course, some "physico-mathematical" subjects, such as elasticity of chords and beams (see Bertoloni Meli 2006, pp. 240–242).



SYNOPSIS LIBRORVM
huius tractatus.

LIBER I. De Impetu.
II. De motu naturali deorſum.
III. De motu violento ſurſum.
IV. De motu in planis inclinatis.
V. De motu mixto ex rectis.
VI. De motu reflexo.
VII. De motu circulari.
VIII. De motu funependuli.
IX. De motu mixto ex circulari.
X. De diuerſis impreſſionibus motus.
APPENDIX I. De centro percuſſionis.
II. De principio Phyſicomechanico.
III. De principio impreſſionis.
IV. De principio rationis duplicatæ.

Fig. 2.1 The *Tractatus physicus's* table of contents

distinctions – the mere decision to include subjects like pendulums and inclined-plane dynamics (introduced by Galileo) could not but obstruct such an intent, and necessarily challenge this old distinction. Aristotelians who wished to remain "up-to-date", i.e. the "progressive" ones among the "Late Peripatetics", could not ignore the pioneering work of Galileo – which included these subjects in the domain of motion, i.e. natural philosophy. As Ugo Baldini observes, in the traditional "disciplinary framework" the "study of motion (essentially everything that falls today under the purview of kinematics and dynamics) was the preserve of the philosophers, being a 'physical' and not 'mathematical' subject" (Baldini 2003, p. 61). In contrast, the area of inclined planes, dealt by Fabri as a "natural philosophy" subject, was traditionally considered – as one of the "simple machines" – as belonging to what we would call statics, i.e. to the old curriculum of mathematics.[25] Baldini discusses the situation within the Jesuit *Collegio Romano* between 1553 and 1612 (Clavius's death); Fabri's *Tractatus*, written only 34 years following 1612, already displays the influence of the New Science (especially Galileo's *Two New Sciences*) on "Late Peripatetics" like Fabri. It is also worth mentioning that the titles "on natural motion downward" and "on violent motion upwards" indicate another important (totally anti-Aristotelian) characteristic of Fabri's physics: the abolition of levity as an intrinsic property of bodies; thus "natural motion" can *only* be downwards, and similarly "violent motion" can occur only upwards (see Section 7.1 below).

But looking closer at this table of contents, we can discern an even more interesting characteristic. The first four *libri* deal exclusively with *rectilinear* motion, while

[25] Baldini 2003, pp. 59, 61–63. See also Consentino 1999, pp. 54–55.

the fifth book describes "mixed motion", i.e. motion created from different rectilinear motions; as we shall later see (Part III will discuss in detail an important example of "mixed motion", namely projectile motion), Fabri's impetus has indeed an inherent "linear" nature. The following books deal with *circular* motion, ending with a book discussing motion created from several circular motions (followed by a "stand alone" book describing "diversely impressed motions"). This distinction between linear and circular motions constitutes the really important division underlying the table of contents, and it is closely connected both with the nature of motion itself, which is intrinsically rectilinear,[26] and with the inherently linear nature of impetus. Perhaps this frame of mind could be seen as a result of a "geometrization" of motion influenced by Descartes' laws of motion: for seeing linear motion as the foremost type of motion contradicts Aristotle's theory – which claimed that "all motion in space (locomotion) is either straight or circular or a compound of the two", but stressed that "circular motion is prior to rectilinear".[27] Part III will demonstrate the highly interesting consequences of Fabri's anti-Aristotelian attitude.

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[26] Concerning sublunary motions, the declared focus of the *Tractatus physicus de motu locali* (Fabri 1646b, *praefatio*, unnumbered page).

[27] *On the Heavens* [Aristotle 1953], 1, 2, 268b17, 269a25.

Fabri, Honoré. 1646b. *Tractatus physicus de motu locali, in quo effectus omnes, qui ad impetum, motum naturalem, violentum, & mixtum pertinent, explicantur, & ex principiis physicis demonstrantur; auctore Petro Mousnerio Doctore Medico; cuncta excerpta ex praelectionibus R.P. Honorati Fabry, Societatis Iesu*. Lyon.

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Chapter 3
Motion

Fabri defines motion as "the transition of a mobile from one place to another by a continuous flux".[1] He immediately remarks that the reader who wishes to further understand this definition could find an explanation in his *Metaphysica demonstrativa*, but "it would not be much use in the present context".[2] Fabri does not wish then to dwell here, in his physical treatise, on the metaphysical subject which had occupied so many medieval philosophers[3] – the ontology of motion, and he seems to exemplify Gabbey's characterization of the "new philosophers", according to which they "cultivated the view that motion is essentially a *simple* category, so that little need be said about its nature, the 'change-of-place' definition being assumed without much reflection" (Gabbey 1998, p. 650). Obviously, Fabri has other concerns in the *Tractatus*; as we shall soon learn, the subjects which interest him the most at the beginning of this specialized physical treatise are the ontology of the *cause* of motion – i.e. impetus – and the causality between impetus and motion.

3.1 Motion and *fluxus*

The term Fabri uses in his (otherwise straightforward) definition of motion – "continuous flux", or "flow" (*fluxus*) – immediately brings to mind the rich medieval tradition which dealt with the ontology of motion, especially concerning the question whether motion can be distinguished from the parameter – or "form" – that undergoes change. Unfortunately, Aristotle's treatment of motion left many questions unanswered, or rather open to too many answers – e.g., to what category

[1]"Motus localis est transitus mobilis e loco in locum continuo fluxu" (Fabri 1646, lib. 1, def. 1, p. 1).

[2]"Huius definitionis explicationem habebis in Metaphysica quae sane explicatio ad rem praesentem non facit" (see also Gabbey 1998, p. 653).

[3]Somewhat later, Fabri similarly refuses to delve into the metaphysical issue of modes (". . . sed de modis in Metaphysica; vix enim hoc Theorema ad rem Physicam quicquam facit"; Fabri 1646, lib. 1, th. 9, p. 17).

M. Elazar, *Honoré Fabri and the Concept of Impetus: A Bridge Between Conceptual Frameworks*, Boston Studies in the Philosophy of Science 288,
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does *motus* belong;[4] a situation which naturally gave the scholastic commentators a vast space for discussion. According to a view identified with Albertus Magnus and Averroes, exemplified by the "reductionist" attitude of Ockham, motion is nothing over and above "*forma fluens*", i.e. a form, or *terminus* of motion (that is, a certain color, or place, or degree of heat etc.) which changes to another *terminus*, and therefore it is not "eligible" for a status of an independent entity. However, the opinion initially ascribed to Avicenna and defended later by Jean Buridan sees motion as a "*fluxus formae*", i.e. a "separate and distinct flowing" which "is not simply identical with the form in a state of flux or with the being that flows" (Maier 1982, p. 26).

According to Dennis Des Chene, the typical view prevailing in what he designates as "central texts",[5] arrives at a kind of compromise between Burdian's realism and Ockham's total reductionism. According to the *Conimbricenses*, "*motus* is not really, but only formally distinct from the *terminus* it aims at", i.e. – in Wallace's words – "each has a different *ratio* or definition";[6] Toletus claims that although "*motus*... is not really distinct from the *terminus* or the form [acquired in passing]", nevertheless local motion and its *terminus* are "distinct in reason and definition".[7]

What is Fabri's opinion in the matter of motion as a "flux", and on the distinction between *motus* and its *termini*? In order to answer these questions we must, naturally, cast aside Fabri's abovementioned "advice" – or perhaps "warning" – not to consult his *Metaphysica*. Book 12 of this work bears the name *De motu locali abstracto*, and Fabri explains that the adjective "abstract" is required because the motions discussed here (unlike those dealt with in the *Tractatus*) belong not only to corporeal objects, but also to incorporeal ones, e.g. angels.[8] The first definition, which concerns local motion, states that "local motion is a mutation of place, by a continuous flux, according to the exigence of something intrinsic". The "intrinsic" entity which is the "exigence" of motion is nothing but the quality of impetus, and this matter will be (extensively) discussed soon; what is relevant to the present discussion, however, is the fact that this time Fabri explains what he means by "continuous flux": it is nothing but a "continuous path, without a jump; for there cannot be motion, unless through a medium".[9] A "continuous flux", then, is not related in Fabri's thought to the ontological status of motion – it does not necessarily imply

[4] See Des Chene 1996, p. 36.

[5] Namely, "running commentaries on Aristotle's text, or *quaestiones* on more or less standard topics suggested by it, or both" – especially works written by Petrus Fonseca, Franciscus Toletus and the Jesuit members of the *Collegium Conimbricenses* (Des Chene 1996, pp. 7–10) – which inevitably helped to mold Fabri's early mode of thought. They belong, of course, to the group characterized by Gabbey as "Late Peripatetics".

[6] Wallace 1972–1974, vol. 1, p. 136.

[7] Des Chene 1996, pp. 38–39; text in brackets – Des Chene's.

[8] Fabri 1648, lib. 12, p. 471 (before def. 1).

[9] "Motus localis est mutatio loci, continuo fluxu, ad exigentiam alicuius intrinseci... dicitur continuo fluxu, id est continuo tractu, sine saltu; nec enim est motus, nisi per medium" (Fabri 1648, lib. 12, def. 1, p. 471).

a *fluxus formae* different from the *termini* of motion; rather, it simply designates a motion unimpeded by any “jumps”.

First of all, it is interesting to find quite a similar remark in Ockham’s *Summulae physicorum*: “For something to be in motion, it is enough that the movable object continuously, without temporal interruption and rest, acquires something one part after another in succession”.[10] In any case, Fabri’s definition is almost certainly directed not towards supporters of either *fluxus formae* or *forma fluens*, but against the philosophy of motion of the Spanish Jesuit Rodrigo Arriaga, who in his *Cursus philosophicus* (1632) claimed that motion is interrupted by instances of rest, or “intermissions”.[11]

But following Fabri’s somewhat newer definition of motion in the *Metaphysica* (compared to the one found in his earlier *Tractatus*), a new question might be raised: what does he mean by saying (while explaining the meaning of “continuous flux”) that there can be motion only “through a medium”? First of all, it is important to emphasize that the word “medium” does not mean some intervening substance (such as air or water) through which a body is carried; as will be shown in Part III, Fabri has no problem with motion in a void. Fabri explains this remark in proposition 19, which declares that “every motion occurs in a place, or space”.[12] For example, in the case of straight motion, “a certain space is acquired, and it is extended, either more or less”.[13] Later in proposition 19 Fabri repeats his statement, that acquiring a new place necessitates a passage through a medium, and supplies an example (Fig. 3.1), which describes an indivisible entity A (usually represented by an angel[14]) that moves to the right:

> If a mobile could move from one place to another without passing through a medium, e.g. if an angel which is in A could move to E, in an instant of time, without passing through B, C, D, then it could acquire a place towards any distance whatsoever; for why should [it be] towards one, rather than another; but this is absurd. Besides, there is nothing by which it could be terminated to move rather to E and not D or C.[15]

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[10] Adams 1987, p. 801, n. 7.

[11] Palmerino 2003, pp. 197, 203. See also Fabri 1648, lib. 9 (*De tempore & duratione*), p. 375, where Fabri rejects the attempt to explain “slowness and swiftness by bigger and smaller delays” (“Dices explicari tarditatem & velocitatem per morulas maiores et monires; apage istas nugas. . .”).

[12] “Omnis motus fit in loco vel spatio” (Fabri 1648, lib. 12, prop. 19, p. 490).

[13] “. . .igitur in motu recto semper erit spatium aliquod acquisitum, illudque extensum, sive plus, sive minus” (Fabri 1648, lib. 12, prop. 19, p. 490).

[14] Fabri claims that “an angel or a physical point” can qualify as an indivisible (Fabri 1648, lib. 12, prop. 17, p. 483). On scholastic disputations (including Suarez’s position) whether an angel may be considered to occupy a point see Sylla 2005, pp. 255–259.

[15] “. . .si mobile posset migrare e loco in locum sine transitu per medium, v.g. si Angelus qui est in A, migrare posset in E, scilicet temporis instanti, sine transitu per B, C, D, ad quamcumque distantiam, locum acquirere posset; cur enim potius ad unam, quam ad aliam; sed illud absurdum est; praeterea nihil est, per quod terminari possit ad hoc ut migret potius in E, quam in D, vel in C” (Fabri 1648, lib. 12, prop. 19, p. 492).

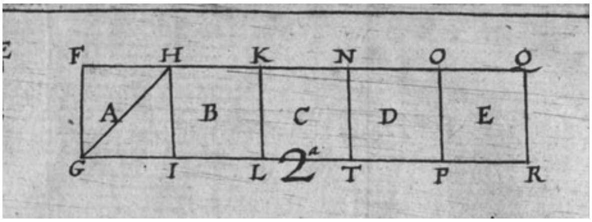

Fig. 3.1 Motion of an indivisible (Fabri 1648, p. 658)

So it is quite clear that the idea of "a passage through a medium" (or perhaps a "middle") is intended for guaranteeing the continuity of motion, i.e. avoiding jumps which are presented, in this example, by an angel moving from A to C, D or E without passing first in B. However, now Fabri adds an interesting line, which closely connects between the notions *fluxus* and *impetus*: "So impetus is a quality, which exacts (*exigit*) the flux of its subject within a space of a place; but a flux occurs through a medium: therefore as much as a mobile is determined by an impetus towards a *terminus*, so it is [determined] towards a medium, as is clear".[16] So Fabri emphasizes that a mobile directed (by an impetus, i.e. the cause of motion) towards any *terminus* must also be directed towards any part of the "medium" (or "middle") that resides between it and that very *terminus*. Now Fabri links all this to an important theme in seventeenth century philosophy of mathematics – the generation of geometrical magnitudes by motion:

> Finally, a straight motion of a point cannot be conceived without describing a straight line, a straight motion of a line [cannot be conceived] without describing a plane, provided that its points do not run through the same track; a motion of a line, around the other fixed extreme, [cannot be conceived] without describing a circle. The geometers suppose these [examples] and many others, which they would not suppose, if something could move from one place to another without passing through a medium.[17]

In the *Tractatus*, while discussing "apriori explanations" (*rationes apriori*) by which the existence of motion must be assumed, Fabri associates again mechanics and geometry, in this very context:

> 6. [Motion is also required] by mechanics itself, which serves instruments for motion: for who would deny that the moment (*momentum*) is bigger when connected to a greater distance; if the moment is indeed greater, will it not prevail? Therefore it will fall downwards.

[16] "…impetus est qualitas, quae fluxum sui subiecti exigit, in spatio loci; sed fluxus fit per medium: deinde tam versus medium est determinatum mobile ab impetu, quam versus terminum, ut patet" (Fabri 1648, lib. 12, prop. 19, p. 492). The important and significance of the verb *exigere* will be explained in due course; by the expression *spatium loci* Fabri apparently means simply a spatial interval.

[17] "Denique non potest concipi motus rectus puncti, nisi describat lineam rectam, motum rectum, lineae, nisi describat planum, modo singula eius puncta eundem tramitem non percurrant; motum lineae, circa alteram extremitatem immobilem, nisi describat circulum; haec & alia multa supponunt geometrae, quae revera non supponerent, si quid e loco in locum moveri posset, sine transitu per medium" (Fabri 1648, lib. 12, prop. 19, p. 492).

> Indeed the stricter geometry, not to mention astronomy, supposes motion, since by flux or motion of a point it describes almost infinite lines. Therefore it is certain that local motion exists.[18]

So Fabri's notion of "flux" seems quite remote from the meaning intended by the medieval supporters of *fluxus formae*, and is clearly connected to his mathematical mode of thought. Although already the ancients occasionally used motion in defining geometrical figures,[19] only in the seventeenth century did this conception – of Pythagorean origin – become "a pervasive practice" (Mancosu 1996, pp. 94–95). In fact, the way in which Fabri connects geometry (in which lines are created by a "flux" of points, and surfaces from that of lines) and local motion (which is created by flux, through the "determination" of impetus) is somewhat reminiscent of Isaac Newton's concept of fluxion. For example, this is what Newton says in his introduction to *De quadratura curvarum*, conveying (like Fabri) the old Pythagorean notion of *continua* which are created by moving indivisibles:

> I do not here consider Mathematical Quantities as composed of Parts extremely small, but as generated by a continual motion. Lines are described, and by describing are generated, not by any apposition of Parts (*per appositionem partium*), but by a continual motion of Points. Surfaces are generated by the motion of Lines, Solids by the motion of Surfaces, Angles by the Rotation of their Legs, Time by a continual flux (*per fluxum continuum*), and so in the rest.[20]

E. A. Fellman investigated Fabri's mathematical thought, and remarked that "through the functional reinterpretation of Cavalieri's concept of indivisibles by means of a dynamically formulated concept of *fluxus*, Fabri approached similar ideas put forth by Newton" (Fellmann 1971, p. 505). Elsewhere Fellman further explains that

> following Cavalieri's method of indivisibles which basically admits only a static interpretation of these elements in an Archimedean sense, Fabri considered this method's novel feature to be the "fluent generation" of geometrical objects, the *fluxus* representing time. This rather dynamical concept of the generation of the continuum by the *fluxus* of an indivisible leads qualitatively to the calculus of fluxions of the Newtonian type. (Fellmann 1992, p. 97)

[18] "Sexta ab ipsa Mechanica, quae organa motui ministrat: quis enim negaret maius momentum esse cum maiori distantia coniunctum; si vero maius momentum est, nunquid praevalebit; igitur deorsum cadet, immo severior Geometria, ut omittam Astronomiam, motum supponit, cum ex fluxu seu motu puncti infinitas fere lineas describat. Igitur certum est dari motum localem" (Fabri 1646, lib. 1, hyp. 1, p. 3).

[19] Aristotle remarked in *On the Soul* that "they say that the movement of the line produces a surface, and the point the line"; Archimedes, Apollonius, Pappus and even Euclid (in book XI, definition 14) used motion to define figures, although the latter preferred to define a line as "a breadthless length". See Mancosu 1996, p. 94, and also Heath's "Notes on Definitions 1, 2" in Euclid 1956, vol. 1, pp. 158–159.

[20] Translated by John Harris, in Harris 1710, vol. 2, s.v. "Quadrature of Curves". The original Latin text appears in Newton 1967–1981, vol. VIII, p. 106.

I am not claiming (neither is Fellman, so it seems) that Newton was directly or personally influenced by Fabri, or that Newton's "fluxion" and Fabri's *fluxus* are comparable. First of all, the origins of Newton's "fluxion" and "fluent" might be traced – with proper qualifications, of course – as far back as Richard Swineshead, who used the terms *fluxus* and *fluens* to advance the medieval theory of *latitudo formarum* (Boyer 1949, pp. 75–79). More importantly, while Newton's notion of fluxion was intimately related to his conception of instantaneous velocity (which in itself was not yet rigorous, in the absence of the concept of limit[21]), there is no trace in Fabri's work to a link between *fluxus* and velocity. It is worth noting that although the very concept of impetus did entail at least some amount of intuitive understanding of instantaneous velocity,[22] Fabri's definition of "swift motion" (i.e. "motion through which a bigger space is run through in an equal time, or an equal space in less time"[23]), exemplifies a standard Aristotelian view,[24] a far cry from Newton's approach. Analyzing in full Fabri's mathematical concept of *fluxus* – i.e. as it is exemplified in his mathematical works – would be outside the scope of this book. However, there is a possibility that this mathematical aspect of *fluxus* – i.e. seeing it as the process by which a point "creates" a continuous line – might have influenced Fabri's "mechanical" thought, namely his concept of motion, and this will be discussed in Part III, which describes Fabri's relatively advanced view in this matter.

Newton himself, referring to the origins of his mathematical "Pythagorean" approach, stated in 1714 that "its probable that D^{r} Barrows Lectures might put me upon considering the generation of figures by motion, tho I not now remember it" (Westfall 1980, p. 131). Richard Westfall finds it "necessary to remark that the idea was not unique to Barrow; it was part of the mathematical culture of the day" (ibid.). Indeed, Paolo Mancosu emphasizes "the connection between the widespread use of motion in mathematics during the seventeenth century and the emergence and flourishing of the mechanistic viewpoint", and lists "Napier, Kepler, Descartes, Fermat, Torricelli, Roberval, de Witt, Wallis, Fabri, Gregorius à S. Vincentio, Gregory, Barrow and Newton as mathematicians who had appealed to the concept of motion in their geometrical investigations" (Mancosu 1996, p. 95). So Fabri's participation in the "mathematical culture" which ultimately swept Newton himself is already well documented. My intention in this book is only to show (in Part III) that Fabri's

21 Boyer 1949, pp. 193–196.

22 According to Boyer, the concept of impetus served "to make more acceptable the intuitive notion of instantaneous velocity, an idea excluded by Aristotle from his science, but implied by the quantitative study of variation of the fourteenth century" (Boyer 1949, pp. 72–73); see also Kuhn 1970, pp. 124–125.

23 "Motus velox est quo percurritur maius spatium aequali tempore, vel aequale spatium minori tempore; contra vero motus tardus" (Fabri 1646, lib. 1, def. 2, p. 1).

24 "The quicker of two things traverses a greater magnitude in an equal time, an equal magnitude in less time, and a greater magnitude in less time" (*Physics* [Aristotle 1930], 6, 2, 232a25). See also Damerow et al. 2004, pp. 13–14.

mechanical ideas (like his mathematical ones) are rather advanced as well, certainly much more progressive than most historians have argued.

Incidentally, Fabri's substantial "dynamic" contribution to Cavalieri's theory of indivisibles did not remain unnoticed during the seventeenth century. Leibniz, commenting on Newton's *De quadratura curvarum* remarked in his *Acta eruditorum* (January 1705) that

> Accordingly instead of the Leibnizian differences Mr. Newton employs, and has always employed, fluxions, which are almost the same as the increments of the fluents generated in the least equal portions of time. He has made elegant use of these both in his *Principia Mathematica* and in other publications since, just as Honoré Fabri in his *Synopsis Geometria* substituted the advance of movements for the method of Cavalieri.[25]

Leibniz's casual remark – certainly made in good faith, especially considering the friendly correspondence between Fabri and Leibniz and the high esteem held by the latter to his older French colleague (see "Introduction" above) – had the unfortunate double effect of not only contributing to the notorious dispute over the discovery of calculus (Newton was convinced that Leibniz had thus deviously accused him with stealing his own ideas),[26] but also of marring Fabri's own reputation for a long time. For example, Moritz Cantor, who became "severely prejudiced against Fabri, successfully blocked interest in his *mathematica* and it was not until the 1950s that a first thorough analysis was carried out" (Fellmann 1992, p. 97).

3.2 Motion as a Relation

Having examined Fabri's attitude (or perhaps lack of attitude) towards the medieval debate concerning the *fluxus*, let us turn to his view on the interesting issue of motion and its *termini*. Once again, Fabri's ideas in this subject do not seem to reflect the scholastic tradition. Unlike the *Conimbricenses* and Toletus, Fabri is not at all interested – neither in the *Tractatus*, nor in the *Metaphysica* – in distinguishing between motion and its *termini*; on the contrary – as we shall now see, he tries to identify them, by using the notion of "relation".

In the *Tractatus* Fabri is content with claiming that motion is "something really distinct from the mobile", basing himself on the difference – contradiction, actually – between "moving" and "not moving",[27] and characterizing motion as a "*resultans, ut relatio*".[28] In the *Metaphysica*, however, he goes into details. Already in the third book of this work, *De ratione entis*, Fabri says that motion may be

[25] Quoted from Hall 1980, p. 138.

[26] See Hall 1980, pp. 129–145.

[27] "Motus est aliquid realiter distinctum a mobili. Demonstratur; Motus est in mobili, in quo ante non erat. . . praeterea moveri, & non moveri sunt praedicata contradictoria, ut constat" (Fabri 1646, lib. 1, th. 1, p. 12).

[28] Fabri 1646, lib. 1, th. 2, p. 13; see Section 4.3 below.

"reduced to relation",[29] and in the sixth book – *De relatione* – he states that "local motion, since it is a passage [*transitus*] from one place to another by impetus, is a relation between the place left behind, the place acquired, the mobile and the impetus".[30] Fabri discusses this issue again in *De motu locali abstracto*. Proposition 16 claims that "local motion consists of three intrinsic principles, which are the mobile, the *terminus a quo*, or place left behind, and the *terminus ad quem*, or place immediately acquired". Without these principles, he explains, motion cannot even be conceived (*concipi*). He concludes that local motion must be "a kind of a relation of simultaneity (*relatio simultatis*)" between the two *termini*, since "neither of them can exist separately, only both together". That simultaneity, repeats Fabri, exists not only between these two *termini* but also with the mobile and the "intrinsic exigence of that mutation" (impetus).[31]

Fabri's characterization of motion as a "relation" is not very compatible with Aristotle's basic system of categories. In his *Categories*, Aristotle explains that the words " 'Double', 'half', 'greater', fall under the category of relation",[32] and hence it seems hardly appropriate to consider also "motion" as belonging to the same category. Furthermore, Aristotle regards motion as something belonging to other categories (quality, quantity and place); again, regarding motion as a "relation" – i.e. identifying an existing independent category with changes occurring in other categories – does not seem consistent. Fabri (no doubt aware of these considerations) agrees that motion should not be considered as strictly belonging to the category of relation, but nevertheless insists that motion "designates an essential order concerning a mobile, [and also] designates a passage from place to place, a passage which cannot be conceived in any way without a 'respect' (*respectus*) or relation".[33]

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[29] Fabri 1648, lib. 3, prop. 20, p. 125.

[30] "…motus localis, cum sit transitus e loco in locum per impetum, est relatio ad locum relictum, ad acquisitum, ad mobile, & ad impetum" (Fabri 1648, lib. 6, prop. 8, p. 203).

[31] "Prop. 16: Hinc motus localis constituitur per tria principia intrinseca, quae sunt mobile, terminus a quo, seu locus relictus, terminus ad quem, seu locus immediatus acquisitus… Nempe illa sunt principia intrinseca motus localis, sine quibus ne concipi quidem potest… Observandum tamen est, motum ipsum seu mutationem illam localem, esse quamdam veluti relationem simultatis, scilicet ex termino a quo, & termino ad quem; quippe neuter esse potest seorsim, sed uterque coniunctim; ita ut dicat, vel locum primo relictum, cui succedit alius immediatus, tum primum, scilicet acquisitus; vel locum immediatum primo acquisitum, quem relictus immediate praecessit, & quo instanti acquiritur novus, prior relinquatur; igitur simultas illa est utriusque, id est desitionis unius, & acquisitionis alterius immediati, cum ordine essentiali ad locatum commune seu mobile, & exigentiam intrinsecam huiusmodi mutationis. Porro illa simultas dici potest relatio, vel modus respectivus, qui certe ab illis omnibus seorsim sumptis distinguitur… Dixi esse quamdam relationem, quia non potest concipi illa simultas, nisi concipiatur unum cum alio coniunctim" (Fabri 1648, lib. 12, prop. 16, p. 480).

[32] *Categories* [Aristotle 1928], 4, 1b30.

[33] "Dices motum non poni in praedicamento relationis; Respondeo, in praedicamento relationis praedicamentalis, concedo; at vero negari non potest, quin motus; v.g. dicat ordinem essentialem ad mobile, dicat transitum e loco in locum, qui transitus nullo modo sine respectu, & relatione concipi potest" (Fabri 1648, lib. 12, prop. 16, p. 480).

Fabri now defines once more that “simultaneity” as a “respective mode”, since “motion cannot exist, nor can be conceived, without a mobile; however a mobile can exist without motion. Therefore [motion] will be correctly called ‘a mode’, as is obvious from what has been said in book 5 [*De accidente*] and if it is a mode, it is not some simple entity”.[34] And in *De accidente* Fabri writes that “every relation can be said to be a mode, as a similitude; likewise every mutation and every motion; thus generation, rarefaction, corruption, condensation, translation (*latio*) and alteration may be said to be modes; indeed an energy of motion (*energia motus*) such as sound can be said to be a mode”.[35]

Alexandre Koyré, characterizing what he defined as the new “Platonic” concept of motion developed by Galileo, remarks that (uniform and rectilinear) motion in this new sense (unlike the old Aristotelian one) “seems to be a relation. But at the same time it is a *state*, just as rest is another *state*, utterly and absolutely opposed to the former; besides which they are both *persistent states*. The famous first law of motion, the law of inertia, teaches us that a body left to itself persists eternally in its state of motion or of rest” (Koyré 1943, p. 418). Without committing ourselves to Koyré’s strict and famous dichotomy between “motion as a process” (the Aristotelian anti-inertial) attitude and the classical (inertial) concept of “motion as a state”, we must admit that Fabri’s identification of motion as a “relation” which is somehow a “state” (mode) is highly interesting in this context, especially since Fabri also explicitly asserted that *pace* Aristotle motion in a void is perfectly possible and would persist forever. Descartes – in his answer to the question “What is meant by ‘motion’ in the strict sense of the term” – also claimed that motion is nothing but a mode of a moving thing “and not itself a subsistent thing, just as shape is a mere mode of the thing which has shape”.[36] As will be shown soon, according to Fabri the concept “mode” is a synonym of the term “modal accident”, of which “shape” is a typical example, to be distinguished from “non modal accidents” like impetus (see Section 4.2 below). However, it was just mentioned that Fabri saw motion as something *really* (i.e. not merely *modally*) distinct from the moving object, so it is must be concluded that he did not regard *motus* as a “standard” mode, i.e. equivalent to “shape” etc, and thus it is hard to claim that he regarded motion as a “state”. Section 4.3 below will further discuss the significance of the real distinction between *motus* and the *mobile* – along with Fabri’s apparently contradicting statement that motion cannot be regarded as a real *ens*.

[34]“. . .simultatem illam dici posse modum respectivum, modum quidem, quia non potest esse, nec concipi motus, sine mobili; potest tamen esse mobile, sine motu; igitur recte dicitur modus, ut constat ex iis quae diximus l. 5, at si modus est, non est aliqua simplex entitas” (Fabri 1648, lib. 12, prop. 16, p. 481).

[35]“Decimo, omnis relatio potest dici modus, ut similitudo; item omnis mutatio, & omnis motus; sic generatio, rarefactio, corruptio, densatio, latio, alteratio dici possunt modi, imo talis energia motus, potest dici modus, ut sonus” (Fabri 1648, lib. 5, prop. 15, p. 172).

[36]*Principles of Philosophy*, part II, art. 25, in Descartes 1984–1985, vol. I, p. 233.

3.3 Motion as *actus entis in potentia*

Before moving on to the subject of impetus, I would like to address one more issue, namely the way Fabri treats Aristotle's definition of motion mentioned above, i.e. what Thomas regarded as the "formal definition" of *motus*: "the fulfillment of what exists potentially, in so far as it exists potentially" (see Chapter 1 above) – known better by the Latin phrase *motus est actus entis in potentia, prout in potentia*.

Aristotle's definition notoriously received endless interpretations, and also – particularly in Fabri's time – many criticisms, some of them derisive. Descartes, for instance, wrote to Mersenne that "someone who walks in a room understands what motion is better than someone who says that it is 'the actuality of a thing in potentiality insofar as it is in potentiality', and so on" (Garber 1992, p. 159).

In the *Tractatus* Fabri refers to this definition only once. After "proving" that impetus exists, Fabri asserts – following Ockham's acknowledgment of the absolute power of God – that even in the absence of this quality, God could move an object.[37] However, Fabri adds that the result of God's action "would not be proper motion, but rather a kind of a mode of continuous reproduction; for motion designates a certain passion (*passio*), an act of an entity in potency, as they say".[38] Fabri perhaps thus emphasizes the importance of impetus – which enables to regard motion as belonging to the category *passio* (i.e. affection), according to Aristotle's *Categories*[39] – without denying God's ability to cause motion (of some sort) in its absence. In any case, apart from this allusion, there is no trace of Aristotle's definition in the whole of the *Tractatus*.

Fabri's *Metaphysica* contains a more elaborate discussion of Aristotle's definition. Already in the first proposition of *De motu locali abstracto* he asserts – as if to defy Descartes, who characterized (in his *The World*) Aristotle's statement as too obscure to even be worth translating (Garber 1992, p. 158) – that "Aristotle's definition of motion, in which he says that *motus est actus entis in potentia, prout in potentia*, can be explained".[40] First Fabri explains the meaning of the term *actus*:

> Because to every potency there should correspond an act, and since an ability to move designates a potency, that [potency] must certainly be reduced to a certain act, which can be none other than motion itself, through which that potency – by which something can move – is reduced to an act; because through it what is capable of motion passes over to motion itself; but let us call the potency itself *mobilitas* and its act – *motus*.[41]

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[37] Ockham declared that "whatever God can produce by means of secondary causes, He can directly produce and preserve without them (Quidquid Deus producit medienatibus causis secundis potest immediate sine illis producere et conservare)"; quoted in Ozment 1980) p. 37.

[38] "...non est dubium, quin Deus sine impetu aliquo modo movere posit... quanquam ut verum fatear non esset proprie motus, sed quasi continuae reproductionis modus; nam motus dicit aliquam passionem; scilicet actum entis in potentia, ut aiunt" (Fabri 1646, lib. 1, th. 18, p. 20).

[39] *Categories* [Aristotle 1928], 9, 11b1–8.

[40] Fabri 1648, lib. 12, prop. 1, p. 472.

[41] "Primo dicitur *actus*; quia cum omni potentiae, actus respondeat, & cum posse moveri, dicat potentiam, illa certe in aliquem actum reduci debet, qui non potest esse alius, ab ipso motu; per quem scilicet potentia illa, qua aliquid moveri potest, in actum reducitur; quia ab eo quod est posse

Now Fabri explains what *entis in potentia* means: "of the mobile, i.e. of that in which the *mobilitas*, or potency for the abovementioned act, exists".[42] For instance, a body is said to be curable (*sanabile*), since it contains *sanabilitas*, i.e. a potency for being cured, and it is likewise said to be heatable (*calefactibile*) if it has *calefactibilitas*, namely a potency "to which heating (*calefactio*) corresponds as an act".[43] Therefore, Fabri concludes, "motion [or change] is the act of that entity, which has a passive potency, or force, because it can move [i.e. change], or undergo a passion (*pati*), or as it were undergo a passion, for it is expressed by a passive voice; for example, being able to be generated, corrupted, rarefied, condensed, altered, locally moved etc."[44] Finally, Fabri clarifies the meaning of *prout* (or *quatenus*) *in potentia*: "naturally motion is not any act whatsoever of that entity in potency, or of the mobile", for the act must match the relevant potency alone. For example, "curing is an act of a curable body, as far as it is curable, and not as far as it is a body, a living thing, a man, etc".[45]

Fabri has indeed demonstrated that Aristotle's definition does make sense, and perhaps does not deserve the ridicule it received by many *novatores*. However, having explained this definition, Fabri never discusses it again in the rest of *De motu locali abstracto*; as already mentioned, in the *Tractatus* – the treatise dedicated to local motion – this definition is mentioned only once (not in a very important context).

Anneliese Maier, discussing the acceptance of Aristotle's definition of motion by medieval philosophers, observes that most of them agreed to it, but that this agreement is nothing but an illusion, because each of them imposed his own interpretation of motion into the phrase *actus entis in potentia* (Des Chene 1996, p. 29). Dennis Des Chene repeats this observation in regard to the early modern Aristotelians whom he discusses (ibid.). Fabri, in contrast, seems to remain loyal to Aristotle's original interpretation, and even succeeds in explaining this definition in a clear and coherent manner. However, beyond this clear explanation (and the somewhat obscure, and in any case totally isolated, remark in the *Tractatus*), he seems not to use it anywhere

moveri, transit ad ipsum moveri; vocetur autem ipsa potentia *mobilitas*; & ipsius actus, *motus*" (Fabri 1648, lib. 12, prop. 1, p. 472; Fabri's emphasis).

[42] "Secundo dicitur actus, *entis in potentia*, id est mobilis; id est eius, cui mobilitas inest, seu potentia ad praedictum actum" (Fabri 1648, lib. 12, prop. 1, p. 472).

[43] "...v.g. corpus dicitur sanabile, quia in eo corporis esse, quod actu est, est sanabilitas, id est potentia ad sanationem (ut sic loquar) quae sanatio est actus eidem potentiae respondens. Pari modo idem corpus est calefactibile, id est huic corpori esse inest potentia, seu vis illa, qua calefieri potest; vocetur calefactibilitas, cui calefactio, tanquam actus respondet" (Fabri 1648, lib. 12, prop. 1, p. 472); cf. *Physics* [Aristotle 1930], 3, 1, 201a10, 201a15.

[44] "...igitur motus est actus illius entis, quod habet potentiam passivam, seu vim, quia potest moveri, seu pati, vel quasi pati, nam passiva voce exprimitur; v.g. posse generari, corrumpi, rarefieri, densari, alterari, moveri localiter, &c" (Fabri 1648, lib. 12, prop. 1, p. 473).

[45] "Tertio dicitur actus entis in potentia, *quatenus in potentia*... nempe motus non est quilibet actus illius entis in potentia, seu mobilis... sed est actus entis in potentia, qui tantum huic potentiae respondet; v.g. sanatio est actus corporis sanabilis, quatenus sanabile, non quatenus est corpus, vivens, homo, &c" (Fabri 1648, lib. 12, prop. 1, p. 473; Fabri's emphasis).

at all. Aristotle's definition appears then in Fabri's text, it is not ridiculed and (unlike Maier's and Des Chenne's impression from other Aristotelians) it seems "untainted" by Fabri's own views; however, as far as I can tell, it literally plays no part at all in Fabri's philosophy of motion. Fabri, as we shall notice over the course of this book (especially Parts II and III), is much too busy trying to incorporate Galilean and Cartesian essentials into his own philosophy of motion than to be bothered by trying to find any significant use for Aristotle's definition of motion within his system.

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Chapter 4
Impetus

The notion of "impetus" has ancient and controversial origins. John Philoponus from the sixth century is often considered the father of the idea of a "force" keeping a projectile in motion, although some historians locate it within a much earlier tradition:

> Samuel Sambursky argues that the idea of impetus was due to Hipparchus of Nicaea (second century BC). Shlomo Pines ascribes it to Alexander of Aphrodisias (third century AD). Henri Carteron has argued that it is to be found first in the pseudo-Aristotelian treatise *De Mechanica*. J. E. McGuire has seen its origins, more generally, in the Stoic thought that later influenced John Philoponus (ca. 490–570), whereas Emil Wohlwill, Pierre Duhem, and, more recently, Richard Sorabji, Michael Wolff, and others trace the idea of impetus to John Philoponus himself. Ernest Moody, without specifying the differences that separate Hipparchus from Philoponus, has attributed to both the originality of the new view. Two other thinkers have also been considered as notable contributors to the progression of ideas which led to the impetus theory: Themistius (c. 317–88 AD) and Simplicius (who wrote after 538, and probably after 532).[1]

As already mentioned (in Chapter 1 above), the Muslim philosophers were the first to implement this idea of an inner moving "force", or "inclination" (*mail*) not only to projectile motion, but also to falling objects (Clagett 1959, pp. 510–514). In any case, the term "impetus" itself (in this context) was coined in the fourteenth century, in order to explain motions that did not fit easily to the Aristotelian scheme, such as projectile motion and free fall of bodies. These "low resistance" or "low friction" motions, having no easily determinable "causes", are difficult to account for within a paradigm that insists on causes for motion[2] and demands constant contact between mover and moved.[3] We have already seen (also in Chapter 1) that Fabri attributed special importance to impetus, far beyond its original scope. In this chapter I shall describe in detail Fabri's conception of impetus and the relation between impetus and motion. Here is Fabri's definition of his favorite physical concept:

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[1]Franco 2003, p. 525. On the "precursors" of impetus in antiquity see also Clagett 1959, pp. 508–510 (projectile motion) and pp. 543–547 (free fall).

[2]By claiming that "everything that is in motion is moved by something"; see beginning of Chapter 1 above.

[3]*Physics* [Aristotle 1930], 3, 2, 202a8.

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> Definition III: impetus is a quality exacting (*exigens*) motion, or flow of place (*fluxus localis*), of its subject; or [the quality] which is the proximate cause of the motion of that mobile in which it is, i.e. in that way in which it can be a cause of motion.[4]

Impetus then is a "quality" causing motion in the subject in which it inheres. But as we can see here, Fabri uses the verb "*exigere*" to describe this causality, and hints that motion in any case could be caused only in a certain way. In order to understand exactly what Fabri means in this definition, we must first describe Fabri's "theory of qualities" (which is to be found in the fifth book of his *Metaphysica*, entitled *De accidente*), and then his full explanation of the relation between impetus and motion (which appears in the first theorems of the first book of the *Tractatus* – *De impetu*).

4.1 Theory of Qualities

Fabri ascribes great importance to "accidents" – meaning especially "physical accidents", i.e. the entities which belong to Aristotle's category of "quality". In fact, it would not be an exaggeration to define Fabri's attitude towards qualities as enthusiastic: "I would dare say", he writes in *De accidente* – using the same phrase he employed to glorify the accident of impetus (Chapter 1 above) – "that the subject of the science [of qualities] is extremely noble and beautiful: for so many things can be known about heat, cold, color, light, sound and impetus".[5] Fabri's excited declaration in favor of qualities could be seen as a protest against Galileo, who in his *Il Saggiatore* (1623) asserted that "tastes, odors, colors, and so on are no more than mere names" which "reside only in the consciousness." (Galilei 1957, p. 274)

In contrast to the *Tractatus*, which regards impetus as a "physical quality",[6] Fabri's *Metaphysica* does not employ the term *qualitas*. In book 2, *De ratione universali*, he enumerates several kinds of qualifying properties (*propria*, or *proprietates*), of which the most important are the following: physical properties, which are really distinct from the objects they predicate (thus "heat" is a physical property of fire); metaphysical properties, which are only formally distinct from the qualified object (visibility is a metaphysical property of man); and modal ones, which are modally distinct from the relevant objects (impenetrability is a modal

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[4] "Definitio III: impetus est qualitas exigens motum, seu fluxum localem sui subiecti, vel quae est causa proxima motus illius mobilis, cui inest, eo scilicet modo, quo potest esse causa motus" (Fabri 1646, lib. 1, def. 3, p. 2). I have adopted Lukens's translation of the verb *exigere*, i.e. "to exact" – a verb closely connected to the Latin source, which unfortunately has some extra meanings in English that might seem confusing. In any case, its meaning in the current context is akin to "require", "compel", or "necessitate"; it actually entails – as will be clearer soon – a kind of causality which is "immediate" and "automatic", as a formal cause should be.

[5] "...imo ausim dicere, pulcherrimum esse, & amoenissimum scientiae subiectum: quam multa enim de calore, frigore, colore, lumine, sono, impetu sciri possunt" (Fabri 1648, lib. 5, prop. 42, p. 181).

[6] Theorem 10 of *De impetu* simply declares: "Impetus est qualitas Physica" (Fabri 1646, lib. 1, th. 10, p. 17).

property of a body).[7] While book 4 (*De substantia*) discusses substances, book 5 (*De accidente*) uses the term *accidentia* to designate any kind of property that pertains to substances. And how does Fabri define an "accident"? An accident, he says, is an *ens* that "inheres or adheres connaturally in another",[8] while an *ens* is "that which either exists or can exist, at least during a certain interval of time".[9] Fabri's conception of *ens* is reminiscent of Suárez's view, which regards *ens* as-a-noun (*ens nomen*) as something that has a "real essence", i.e. involves no contradiction, whether it actually exists or is a mere construction of the mind.[10]

An accident that "inheres" in a substance is defined by Fabri as a "non-modal accident" (equivalent to a "physical property" defined in *De ratione universali*), while an accident that "adheres" to it is a "modal accident", or mode (i.e. a "modal property"). The two kinds of accidents are opposed, Fabri emphasizes, to the concept of "substance": for example, "whiteness exists inside (*inest*) a wall in such a way that it does not subsist (*subsistit*) in it". So what is the difference between "non-modal" and "modal" accidents? Fabri answers: "what inheres could, by a miracle, exist outside the subject, and accordingly not inhere, as we shall find out in the case of the Eucharistic accidents",[11] while what "adheres" could never – not even by a miracle – exist on its own.[12] By defining a "modal accident" – namely, a mode – as a term that maintains a one-way separability with the *res* to which it adheres (this *res* could exist without the adhering mode, but not vice versa) Fabri is again echoing a Suárezian doctrine: namely, his important theory of modes and modal distinction.[13] As Stephen Menn explains, positing a third kind of a distinction, a modal

[7] "Prop. 63: Explicari possunt illa omnia, quae ad proprium pertinent... Quarto, proprium physicum est quod realiter physice distinguitur ab eo cuius proprium est, v.g. calor est proprietas ignis, sed physica; metaphysicum est quod tantum formaliter, non realiter [distinguitur], sic visibilitas est proprietas hominis, sed metaphysica; aliud est modale, quod modaliter tantum distinguitur; sic impenetrabilitas est proprietas corporis" (Fabri 1648, lib. 2, prop. 63, p. 70).

[8] "Definitio prima: Accidens est ens, quod alteri inhaeret, vel adhaeret connaturaliter" (Fabri 1648, lib. 5, def. 1, p. 163).

[9] "Ens est id, quod vel existit vel potest existere, saltem, pro aliqua temporis differentia" (Fabri 1648, lib. 3, def. 1, p. 78).

[10] Suárez adds to this kind of *ens* also "*ens* as-a-participle" (*ens participium*), which signifies actual existence. However, his adoption of the Nominalist rejection of Thomas's real distinction between essence and existence necessarily dims the distinction between these two types of *ens*, which ultimately amounts to a difference in degree of precision. See Copleston 1993, pp. 358–359, 365–368; *Disputationes metaphysicae*, disp. 2, sect. 4, nn. 3–4 & disp. 2, sect. 4, n. 12 & disp. 31, sect. 6, n. 13, in Suárez 1856–1878.

[11] Part IV below deals with Fabri's explanation of the Sacrament of the Altar.

[12] "Definitio secunda: Inhaerentia est ratio formalis connaturalis accidentis non modalis; adhaerentia vero modalis. Utraque opponitur subsistentiae, de quo infra; porro inhaerere, est alteri subsistenti inesse, non tamen in eo subsistere, v.g. albedo ita inest parieti, ut in pariete non subsistat: differt inhaerere ab adhaerere, quod inhaerens possit per miraculum existere extra subiectum, ac proinde non inhaerere, ut videmus in accidentibus Eucharisticis" (Fabri 1648, lib. 5, def. 2, p. 163).

[13] *Disputationes metaphysicae*, disp. 47, sect. 2, n. 9, in Suarez 1856–1878; see Menn 1997, pp. 246–247.

one, between the two admitted by Thomas (real distinction and rational distinction) – i.e. showing that certain kinds of accidents (e.g. relations and figures) must be more than rationally (or mentally), though less than really, distinct[14] – enabled Suárez to both retain some degree of traditional realism and yet adopt the Nominalist criticism against real distinctions.[15]

4.2 The Non-Modal Accidents: Impetus and Heat

Returning to Fabri: which accidents, according to his theory, are "non-modal" – i.e. separable (only by a miracle) – and which are "modal", i.e. inseparable (even by a miracle)? The only qualities which Fabri characterizes as "non modal" accidents in the book *De accidente* are impetus and heat. Why are impetus and heat "non-modal" accidents, while the remaining corporeal accidents[16] are "modal" (i.e. modes)? The answer, explains Fabri, is that impetus and heat are the only two accidents that beyond being inside subjects can also cause some extra phenomena: as he explains, "impetus exacts motion of its subject, and heat – rarefaction".[17] Unlike modes (not to mention accidents which are only formally distinct), impetus and heat have not only a "primary formal effect" (i.e. residing in a subject), but also a "secondary formal effect", motion and expansion, or rarefaction (or *resolutio*, disintegration): as Fabri explains, we can perceive impetus and heat by the mere "mutations" – i.e. motion and expansion – which they cause in the subjects in which they inhere.[18]

By contrast, a modal accident – that is to say, a mode – "which cannot be conceived without a subject [existing] in act, maintains [*praestat*] nothing in a subject, except itself; e.g. extension brings about [*facit*] only [something] extended; duration, only [something which] endures... for were it to bring about something distinct from itself; no doubt it could be conceived in the terms of that thing; therefore [in that case] it could be conceived without a subject [existing] in act, which is against the [original] hypothesis".[19] Such modes – which consist of every possible corporeal

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[14] A real distinction between two terms implies, of course, a two-way separability, i.e. each of them could exist without the other.

[15] Menn 1997, pp. 242–250. Menn claims (ibid., pp. 230–231) that realists do not "multiply *res* according to the multiplicity of the terms, as the Nominalist caricature suggests", and sees them as those who "think that the common nature signified by a universal term (such as humanity) is not another *res* really distinct from its individuals, but is distinguished from them only in some lesser way".

[16] i.e. excluding, e.g. metaphysical accidents, which are only formally distinct from their subjects.

[17] "... vocabimus infra effectum formalem secundarium; sic impetus exigit motum sui subjecti, calor rarefactionem" (Fabri 1648, lib. 5, prop. 5, p. 165). The reason Fabri uses the verb *exigere* will be given in the next section, dealing with the causality between impetus and motion.

[18] Fabri 1648, lib. 5, prop. 19, p. 173.

[19] "Accidens quod non potest concipi sine subiecto actu, nihil praestat subiecto nisi seipsum; v.g. extensio facit tantum extensum; duratio, durans... Si enim aliud faceret a seipso distinctum, haud dubie posset concipi per ordinem ad illud; igitur posset concipi sine subiecto actu, quod est contra hypothesim" (Fabri 1648, lib. 5, prop. 9, p. 169).

property, except impetus and heat (Fabri adds to extension and duration additional modes, such as color, humidity, dryness opacity, impenetrability and hardness[20]) – "have indeed a primary formal effect, but no secondary one... because the latter designates something distinct from the communication of the accident itself".[21] As will soon be demonstrated, Fabri sees this "secondary formal effect" as a kind of goal (*finis*) of the non-modal accident – thus ascribing an "intent", or even a "desire", to a mere accident (rather than to a substance).

These two non-modal accidents, impetus and heat, are responsible for many phenomena in the universe. At the very beginning of *De accidente* Fabri announces, for example, that without impetus earthly bodies would not have been heavy, and the stars would not have revolved in their trajectories.[22] Later he defines the "secondary formal effects" of impetus and heat as "accidental mutations" (*mutationes accidentales*), and adds that "in sublunary bodies there are only two mutations: without the first [the result of impetus], there would occur no mixture; without the second [the result of heat], no disintegration", since unless "particles of mixables" could move, condense or rarefy, all the phenomena pertaining to the forming and disintegration of mixtures would have been impossible.[23]

Fabri's view concerning the two non-modal accidents of impetus and heat can be seen as an attempt to formulate a kind of a synthesis between the fashionable atomistic approach, which tried to reduce all phenomena to neutral (i.e. devoid of any quality or "accident") matter and pure motions,[24] and standard scholastic philosophy. Fabri openly conveys his dissatisfaction with official scholastic physics in a letter to Mersenne, in which he regards it as a discipline "full of disputes", worthy of being called only "elementary metaphysics" or "superior grammar", while true (and "delightful") physics must employ mathematics, and should also involve asserting "natural effects" and ultimately reducing them to causes (i.e. the two non-modal accidents).[25]

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[20]Fabri's especially anti-Aristotelian reduction of humidity and dryness (two of the four "primary qualities") to modes was hardly welcomed by the Jesuit authorities (see Chapter 18, Note 17 below).

[21]"Accidens quod nihil praestat subiecto, praeter seipsum, habet quidem effectum formalem primarium, sed nullum secundarium... quia hic dicit aliquid distinctum ab ipso accidente communicatio" (Fabri 1648, lib. 5, prop. 10, p. 169).

[22]Fabri 1648, lib. 5, p. 163 (just before def. 1).

[23]"Effectus ille secundarius est quaedam mutatio accidentalis... vero singulares sunt prorsus duae illae mutationes, in corporibus sublunaribus, sine prima, nulla fieret mixtio; sine secunda, nulla resolutio, nisi enim particulae miscibilium moveri non possent, quonam pacto coirent, vel avolarent; & nisi densari, vel rarescere valerent, quonam pacto, vel concrescerent, vel exhalarentur" (Fabri 1648, lib. 5, prop. 26, p. 175).

[24]In this sense, the term "atomists" included – in the eyes of Fabri's milieu at least – also Descartes and his followers. On the common contemporary identification of Cartesians with atomists, see Armogathe 2005, p. 156.

[25]This letter is dated 9.8.1643: "... vero tanta est rerum physicarum et mathematicarum communio, ut nullus fere sit in Physica tractatus qui mathesi carere possit. Porro cum *Physicam* appello, nolim, quaeso, intelligas litigiosam illam quam vulgo in scholis nostri philosophi docent quamque

In any case, the importance of impetus and heat to Fabri's "synthetic scheme" did not diminish throughout his long career. As we recall, *Metaphysica demonstrativa* was written in the late 1640s; in 1671, in a letter to the young Leibniz, Fabri explains that he has accepted, in the books he has written in that period, the existence of only six "corporeal things": the four elements, "and two principles of two sensible mutations, of place and of extension; for nature needs both for various resolutions (*resolutiones*)". "Indeed the whole of nature", continues Fabri, "is in motion; therefore it needs a principle of this motion, or local mutation, which I call 'impetus' ". Now Fabri describes his version of "atoms", which contrary to those depicted by Democritus, can change their size: any matter which evaporates, "which was before heavier than air… must become thinner, i.e. more extended". Fabri rejects the claim of the "standard" atomists, that a given volume of air contains atoms within huge amounts of vacuum: "[to claim] that in a cubic palm of air the ratio of body, or material to intercepted vacuum is 1 to 1000 is against common sense. For a cubic palm of air, especially by employing mechanical force, can be reduced by compression to a cubic digit". Fabri apparently means that if air really contained so much vacuum, we would have been able to compress a "cubic palm of air" much more than we actually can. Fabri concludes that "therefore it seems I should accept – within a suitable body – a principle of a bigger extension, which I call heat". With these two principles then, impetus and heat, along with the four elements, Fabri thinks he can explain motion, expansion, contraction etc. of "atoms" – or "mixable entities" (*miscibilia*) – which result in the constantly changing nature we observe: "thus content with those six things, without anything else whatsoever, I tried to explain all natural effects from those very simple principles, which are Peripatetic to the letter".[26] Fabri then accepts the "Peripatetic" (though un-Aristotelian) notion of non-modal, i.e. more or less "independent" qualities, but implements it only to qualities involving motions. A similar "synthetic" (or eclectic) mode of thought is apparent in Fabri's chemical theory, which as Dennis Des Chene

potiori iure elementarem metaphysicam seu grammaticam superiorem appellandam esse censeo, sed iucundam illam quae naturales effectus primo explorat sensu, tum vero ad suas causas reducit"; Tannery et al. 1945–1988, vol. XII, p. 276; Fabri's emphasis.

[26] Gerhardt 1960–1961, vol. 4, p. 243: "Videris in rebus corporeis sex tantum a me admitti, nimirum quatuor elementa communia… et duo principia mutationum duarum sensibilium, nimirum loci et extensionis; natura enim utraque indiget ad varias resolutiones. Immo tota natura in motu est; unde opus illi fuit principio huius motus seu mutationis localis, voco impetum; nisi autem aliquae partes leviores seu minus graves evadant, nunquam ab illis attolli possent ad aelquilibrium; nunquam revera fumus ascenderet, nisi ab aere graviore sursum truderetur. Illa autem materia, quae ante gravior erat aere, pura oleum, humor, aut alius succus exhalabilis, rarior fieri debet, id est magis extensa: quod enim omnes elementorum particulae sint aeque extensae, dici non potest: recurrunt ad haec vacuola Democritici, sat scio; sed quod in palmo aeris cubico ratio corporis seu materiae sit ad vacuum interceptum ut 1 ad 1000, sensui communi repugnant. Potest enim palmus cubicus aeris, adhibita praesertim potentia mechanica, reduci per compressionem ad digitum cubicum; unde maioris extensionis principium, in corpore scilicet capaci, mihi admittendum esse videtur, voco calorem. Itaque sex istis rebus contentus, citra quodlibet aliud, omnes effectus naturales explicare conatus sum ex simplicissimis principiis, iisque peripateticis ad literam".

has shown, managed to be "corpuscularian" (assuming *minima naturalia* of the abovementioned four elements) without violating essential Aristotelian principles like hylomorphism and homeomerism (Des Chene 2001, pp. 378–379).

4.3 The Relation Between Impetus and Motion

Having defined the notion of impetus Fabri compares himself to a Geometrician who defines a circle without committing himself to its actual existence; he claims that later, with the help of theorems, he will prove the existence of impetus.[27] But before attempting this, Fabri takes great pains to establish the adequate causal relation between impetus – "a quality exacting (*exigens*) motion" – and the motion "exacted" by it. As we recall, the first theorem of *De impetu* (the first book of the *Tractatus*) states that motion is "something really distinct from the mobile" (see Section 3.2 above). Fabri needs to establish motion as an object separate from the moving object, otherwise he would be forced to retreat to Ockham's ontology, that refused to accept motion as an "objective" entity and treated it as a merely "convenient" way of describing a body and the consecutive places it occupies (Adams 1987, pp. 819–822). Such an attitude would of course immediately render the whole notion of impetus totally useless, and clearly this is not what Fabri is after. However, what is more interesting is that Fabri – despite stating that motion is really distinct from the *mobile* – also refuses to adopt the other extreme position, namely the "realist" assumption that motion is a "full-fledged" entity by itself.

We have already noticed, in Chapter 3, Fabri's attempt to define the elusive essence of this entity: in the *Metaphysica* he sees *motus* as a kind of "a relation of simultaneity (*relatio simultatis*)", or a "respective mode", leaving the issue of the "positive" definition of this entity rather vague and open to many interpretations. In the *Tractatus*, as we have seen, regarding the "positive" definition of motion, Fabri is willing to say only that on the one hand it is really distinct from the mobile, and on the other hand it is merely a "*resultans, ut relatio*". Other than these remarks – which do not seem mutually compatible – he almost entirely avoids the question "what is motion", and even tries to dissuade the reader from consulting the *Metaphysica*, in which this subject is taken up. However, already in the second theorem of *De impetu* we are given a clear and decisive statement regarding the "negative" characterization of motion, i.e. an explanation of what it is *not*: just as Descartes claimed that motion is not something "subsisting" in the mobile (Section 3.2 above), Fabri asserts here that motion is not really an "*ens*",[28] because it is not "produced" (*producitur*), and "it is not an immediate effect of an efficient cause." The reason Fabri gives for this statement is that only a real entity – an *ens* – can be "produced", while local motion

[27] Fabri 1646, lib. 1, def. 3, p. 1.

[28] See Section 4.1 above for Fabri's definition of *ens*.

has to signify simultaneously the place already left and the place just acquired,[29] and therefore it is not eligible for the title "pure *ens*", and thus cannot be said to be "properly produced":

> You'll say:[30] motion is an entity, not [existing] by means of itself; therefore [existing] by means of another; therefore motion is produced. I answer that motion is not an independent entity, but is a mutation of an entity, a mutation which is some composition of an entity and a non-entity; which certainly cannot be said properly speaking to be something produced, rather it is a resultant, like a relation.... And there is no reason for some people to be so surprised that I say this; since it is certain that secondary formal effects of principle qualities are such, that they are not produced at all; rather, they as it were result by an exigence, e.g. the effect of heat in its subject is the expansion of that subject, which actually is not produced, as is well-known.[31]

So motion, as a "resultant", "relation" or a "respective mode" is not a "pure *ens*", and therefore is not really "produced", but rather "exacted" (*exigitur*) as a "secondary formal effect" by the quality of impetus. In theorem 3, which declares that motion "exists by means of something else distinct belonging to some type of a cause", Fabri adds that motion "is the goal, or secondary formal effect, which the impetus exacts."[32] This is then the causal connection Fabri chooses to define between impetus and motion: the impetus, a physical non-modal quality that inheres in a subject, causes motion as a "secondary formal effect".

To further clarify his view, Fabri – in the scholium to theorem 3 – distinguishes between two types (*genera*) of motion: the first one involves direct contact between the mover and the moveable (e.g. a projectile, just before leaving the projecting agent), while the second one pertains to bodies which move without an apparent mover (e.g. the same projectile, having been hurled). The first *genus* of motion is, according to Fabri,

[29] "Motus est mutatio, seu transitus ex loco in locum per def. 1, sed mutatio proprie non producitur; quippe productio tantum terminatur ad ens; nihil enim nisi ens produci potest; atqui nulla mutatio dicit tantum ens; praesertim haec, quae tantum dicit terminum a quo, id est locum relictum; & terminum ad quem, id est locum immediatum acquisitum; nam separato quocunque alio ab ipso mobili; modo simul, id est eodem instanti relinquat primum locum, & novum acquirat, omnino movetur, sed concretum illud ex loco relicto, & acquisito produci non potest" (Fabri 1646, lib. 1, th. 2, pp. 12–13).

[30] This objection was likely to have been raised by Fabri's "realist" colleagues.

[31] "Dices Motus est ens, non a se; igitur ab alio; igitur motus est productus. Respondeo motum non esse ens absolutum, sed esse mutationem entis, quae mutatio est concretum quoddam ex ente & non ente; quod certe non potest dici proprie productum, sed resultans, ut relatio... Nec est quod aliqui ita mirentur haec a me dici; cum certum sit effectus formales secundarios principum qualitatum tales esse, ut minime producantur; sed quasi resultent ab exigentia; v. g. effectus caloris in suo subiecto est eiusdem subiecti rarefactio, quae revera non producitur, ut constat" (Fabri 1646, lib. 1, th. 2, p. 13).

[32] "Motus est ab alio distincto in aliquo genere causae... hoc est finis, vel effectus formalis secundarius, quem exigit impetus" (Fabri 1646, lib. 1, th. 3, pp. 13–14; as mentioned above, the "primary formal effect" of impetus is simply residing in the subject). I do not know of any other philosopher who used the verb *exigere* in this peculiar manner, which distinguishes it so strictly from the verb *producere*.

> the action of the motive force (*potentia motrix*), which really moves (*movet*)[33] and whose effort is said to be motion (*motus*), or translation (*latio*), or movement (*motio*), or action, by which it really acts, and produces impetus, not motion; because it is exhausted even without motion, e.g. when someone pushes someone else, by whom he is pushed by equal exertion;[34] it is also evident in a hand which does not move when holding a weight; even if [the hand] really acts with its highest effort.[35]

Fabri now analyzes this type of motion in standard Aristotelian terms, and claims that from the point of view of the motive force, this "first kind of motion" it is "an influx, or action", while from the point of view of the subject, "or the mobile, it is an affection (*passio*)"; Fabri sees it as merely a "way by which" the mobile "tends to a *terminus*".[36] Later Fabri explains that in such a motion, the longer a projectile (e.g. a stone) is moved prior to the throw, the stronger the impetus and the resulting throw become; this is also why a preceding run increases the distance of a jump.[37]

The second kind of motion is the "mutation, or transition from one place to another; it is the goal, or secondary formal effect, which the impetus exacts".[38] This type does not entail a constantly attached mover, and pertains (e.g.) to a stone after leaving the projecting hand or simply falling to the ground. As will be shown below, Fabri could have found a similar division in Franciscus of Marchia's analysis, though not in Buridan's. Significantly, in the first type of motion, in accordance with general Peripatetic thought, the substance is emphasized: it is seen as a "subject" which while moving undergoes a *passio* and thus can reach its *terminus*; furthermore, this kind of motion necessarily implies an "exhaustion" of the mover (even if no motion actually occurs). However, in the second type of motion the quality (impetus) "takes over": once it is inserted inside the subject it "wishes" to fulfill its "goal" (or "exact its secondary formal effect"), i.e. to move the subject in which it inheres. The emphasis has now shifted from substance to one of its accidents – quality. Perhaps the most impressive manifestation of this "quality-centered" mode of thought is Fabri's statement that an unhindered impetus "would without doubt

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[33] i.e. "moves" in a transitive sense.

[34] Curiously, this brings to mind Newton's third law, i.e. the law of action and reaction.

[35] "Observabis motum localem esse duplicis generis; primum genus motus est actio potentiae motricis, quae revera movet, & cuius exercitium dicitur motus, seu latio, seu motio, seu actio, qua revera agit, producitque impetum, non motum; cum etiam sine motu defatigetur, ut cum quis alium pellit, a quo pellitur aequali nisu; patet etiam in manu sustinente aliquod pondus, quae non movetur; licet revera etiam summo conatu agat" (Fabri 1646, lib. 1, th. 3, p. 13).

[36] "Itaque hic motus primi generis, si comparetur cum potentia motrice, est vere influxus, vel actio; si cum termino, est eius fieri, seu dependentia; si cum subiecto, seu mobili est passio; nec proprie dicitur produci, nisi ut quo (ut vulgo loquuntur) nec enim actio est terminus, vel effectus, in quo sistat causa; sed est via, qua tendit ad terminum" (Fabri 1646, lib. 1, th. 3, p. 14).

[37] "Hinc vt quis maiore nisu lapidem v. g. proijciat, tum longiore tempore brachium rotat, tum praeuio cursu impetum auget, quia non tantum impetus brachii imprimitur mobili, sed etiam impetus totius corporis; hinc etiam si praemittatur cursus longiore saltu in plano horizontali maius spatium traiicitur" (Fabri 1646, lib. 4, th. 99, p. 187).

[38] "Motus secundi generis est mutatio, seu transitus ex uno loco in alium; hoc est finis, vel effectus formalis secundarius, quem exigit impetus" (Fabri 1646, lib. 1, th. 3, p. 14).

rejoice in its goal", i.e. in motion.[39] The "anthropomorphic" tone often used by Aristotelians to describe substances, which "crave" to fulfill some goal – resulting from the constant "yearning" of matter for form – is now applied to form itself. Moreover, this second type of motion – as will be clearer in Part III – does not entail any "exhaustion" of the moving cause (impetus), and thus the conservation of motion (barring hindrances) in not only possible, but necessary.

In theorem 4, Fabri continues to delineate the impetus-motion causality, and claims that following theorem 2 (according to which motion does not have an efficient cause) and theorem 3 (which insists that motion nevertheless does have a cause), the "immediate cause of motion, which is not efficient, can only be exacting (*exigens*), which is reduced to a formal [cause], that exacts its secondary formal effect, namely its intrinsic goal. This is how heat exacts expansion (or disintegration) [and] impetus motion".[40] In theorem 15 he emphasizes again that "motion is a secondary formal effect of impetus, because it is an exacting cause" which "as already has been said. . . is reduced to a formal one".[41]

Fabri has now solved the problem he had raised in his definition of impetus: by characterizing the specific nature of the causal connection between impetus and motion as "formal" rather than "efficient", while intimately associating formal causality with the verb *exigere*, and efficient causality (the kind of causality involved in the creation of real *entia*) with the verb *producere*. Let us now briefly consult the inventor of the scholastic "formal cause" – Aristotle himself, who arrived at this kind of causality due to his dissatisfaction (conveyed at length in his *Physics*, and again in his *Metaphysics*) from earlier accounts of causality. As Francis Aveling explains, in the entry "Cause" of *The Catholic Encyclopedia*, "the Ionians of the older schools had dealt with matter. Later Ionians had treated vaguely of efficient causes. The method and moral teaching of Socrates had convolved and brought out the idea of the final, while Plato had definitely taught the existence of separated formal, causes" (Aveling 1908). Unlike Plato's Ideas, Aristotle's formal cause is to be found inside particulars: it is "described as that substantial reality which intrinsically determines matter in any species of corporal substance. It is conceived as the actuating, determining, specifying principle, existent in the effect" (ibid.). According to Aristotle, a form necessarily exists only inside a particular body: it is the actual aspect of any process or state in which this body might be found, while its matter – the "material cause" – is the "potential", passive aspect of it. This is how Aristotle solved the ancient problem of change: change, or motion, does not involve an existence – i.e.

[39] ". . . cum enim motus sit finis intrinsecus impetus; certe si nihil impediret motum, haud dubie gauderet impetus suo fine" (Fabri 1646, lib. 1, th. 44, p. 32).

[40] "Causa illa immediata motus, quae non est efficiens, potest tantum esse exigens, quae reducitur ad formalem, quae suum effectum formalem secundarium, id est suum finem intrinsecum exigit. Sic calor exigit rarefactionem, vel resolutionem, impetus motum; cum enim non sit causa efficiens per Th. 2. sit tamen causa per Th. 3." (Fabri 1646, lib. 1, th. 4, p. 14).

[41] "Motus est effectus formalis secundarius impetus. Cum enim sit causa exigens. . . Voco effectum formalem secundarium, quem in mobili exigit impetus; quippe, ut iam dictum est, causa exigens reducitur ad formalem" (Fabri 1646, lib. 1, th. 15, p. 19).

a body in a certain state (with a certain quality, or in a certain size, or occupying a certain place) – erupting from nothingness, but rather it entails actual existence evolving out of potential existence. A form, Aristotle says, is "not separable except in statement";[42] although it does not have to be intrinsically dependent of matter – the soul, the formal cause of man, is the obvious example – nevertheless not only can it not exist, but it has no meaning outside a subject, i.e. devoid of matter, the passive aspect of reality. The important point is that Aristotle's formal cause – like the other three – is a concept ultimately based on the existence of an individual body: as Aveling explains, forms "are conceived as informing corporeal substances already existent in entities".[43]

Aveling also mentions Aristotle's final cause, which (as quoted above) "the method and moral method teaching of Socrates had convolved and brought out". As we have just seen, finality is not absent from Fabri's discussion of the causality of motion: he ascribes finality (i.e. an end goal) to impetus, and sees this "final causality" as a reciprocal relation to the "formal causality" of motion; impetus is the formal cause of motion, while motion is the final cause (i.e. "goal", *finis*), or effect, of impetus. It is no coincidence that in Fabri's eyes, saying that "the effect of impetus is motion" is equivalent to claiming that "the goal of impetus is motion". In the beginning of the *Tractatus*, Fabri first explains that a non-modal accident (namely, impetus or heat) must exist in another thing – i.e. in a subject – "because of its intrinsic goal, which we elsewhere call a secondary formal effect".[44] Right afterwards, contrary to Aristotle's basic notion of final cause, and in accordance with the general tendency of seventeenth century thinkers (Aristotelians and *novatores* alike) – to reduce (though not to eliminate) the teleological aspect of physical processes[45] – Fabri warns his reader in the *Tractatus*: "when you hear the word 'goal' (*finis*), I ask you not to think about something moral, for I do not know of such a goal, to which [an accident] is determined by a rational agent".[46] Later in the *Tractatus*, Fabri further explains that "we know the goal of natural things from their behavior itself (*ex ispo usu*); indeed 'goal' is the same as the behavior itself; so since impetus has only that behavior which we observe it to cause in the mobile itself – i.e. motion – it should be claimed that motion is the intrinsic goal of impetus". Fabri now claims that impetus without its "goal" (i.e. "effect") would be in vain, "therefore in order to exist, it has to have that without which it cannot exist". He concludes that motion

[42] *Physics* [Aristotle 1930], 2, 1, 193b3.

[43] Aveling 1908. Indeed, even the primary mover, Aristotle's "pure actuality", has no real sense on its own, i.e. without a material world whose eternal motion is a result of a "desire" for the unmoved mover (*Metaphysics* [Aristotle 1908], 12, 7, 1072a26).

[44] ". . . si vero accidens est, haud dubie alteri inesse debet propter suum finem intrinsecum, quem alibi effectum formalem secundarium appellamus" (Fabri 1646, lib. 1, ax. 6, p. 7).

[45] See Osler 2001, pp. 151–168.

[46] ". . . cum vero audis finem: ne quaeso cogites aliquid morale, nec enim illum finem intelligo, ad quem ab agente rationabili destinatur" (Fabri 1646, lib. 1, ax. 6, p. 7).

is the impetus's "*bonum*, therefore goal, to which it desires by its innate, or native, appetite".[47]

Fabri's notion of finality – devoid of any "moral" meaning, and ascribed to accidents (rather than full-blown substances) – is of course a far cry from Aristotle's concept of final causality. Aristotle's final cause, i.e. the end, or "that for the sake of which the effect, or result of an action, is produced" (Aveling 1908), is always associated with concrete substances, i.e. hylomorphic compositions of matter and form. Aristotle's well known examples from the *Physics* – taken almost exclusively from the realms of "art" or biology – illustrate his emphasis on substances: a builder building a house, a doctor healing a patient, a swallow making a nest, a spider spinning a web etc.[48]

Fabri's concept of final causality was, therefore, rather characteristic of contemporary physical thinking: by the seventeenth century even "conservative" Aristotelians rarely considered the teleological aspect of physical processes as important as Aristotle did; while as Margaret Osler has shown, even extreme *novatores* like Pierre Gassendi and Robert Boyle by no means abandoned physical final causes altogether (Osler 2001, pp. 158–167). Interestingly, Fabri's notion of *formal* causality reflects, on one hand, medieval thought – which had to adapt Aristotle's basic philosophy to Christian anti-Aristotelian doctrines (e.g. Creation, the soul's immortality, and the Eucharist) – and on the other hand it eventually enables Fabri (as will be shown later) to adopt modern principles concerning motion. We have seen above that what differentiates between non-modal accidents (impetus and heat) and modal accidents (all the other qualities) is exactly what Aristotle adamantly prohibits concerning forms: their ability to exist separately of matter. Part IV will outline how Fabri substitutes impetus for Aquinas' quantity as the accident which is "responsible" for the miracle of the Eucharist. In this part we have already seen how impetus serves as the formal cause of motion, while motion is considered as the "goal" of impetus, in which the latter "rejoices": thus a form, or a quality, receives in Fabri's analysis a function which Aristotle explicitly forbade – a form, according to Aristotle, "cannot desire", since by definition "it is not defective"; "the truth is", Aristotle continues to explain, "that what desired the form is matter, as the female desires the male and the ugly the beautiful".[49] Fabri's impetus, which is no longer exclusively dependent on matter, is able – unlike Aristotle's form – to "rejoice" in fulfilling a desire of its own: to move the subject in which it inheres. In Aristotle's thought, the goal of motion is for the substance to acquire a new form,

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[47]"... finem enim rerum naturalium ex ipso usu cognoscimus; immo idem est finis cum ipso usu; cum igitur impetus illum tantum usum habeat, quem in ipso mobili praestare cernimus, scilicet motum; dicendum est motum esse finem intrinsecum impetus; adde quod cum frustra sit impetus ille, qui non praestat motum mediate saltem in suo subiecto; quid enim aliud in suo subiecto praestaret, quem effectum, quam mutationem? Certe si frustra est, non est... igitur ut sit, debet habere id, sine quo esse non potest; igitur maximum eius bonum est, igitur finis, quem nativa vel innata velut appetentia concupiscit, vel exigit" (Fabri 1646, lib. 1, th. 16, p. 19).

[48]*Physics* [Aristotle 1930], 2, 1, 192b23–30 & 2, 8, 199a26–27.

[49]*Physics* [Aristotle 1930], 1, 9, 192a20–23.

or a new accident (a new quality, quantity or place); in Fabri's scheme – which could be described as "quality-centered" (in contrast to "substance-centered") – this explanation is turned upside down: a form inhering in a subject desires to set it in motion; i.e. motion, instead of being the *means* to acquire a new form (owing to the "yearning" of matter to form), is now the *goal* of form.

Unsurprisingly, in the *Tractatus* we can still see – alongside Fabri's unique conception of impetus and motion just described – traces of the old Aristotelian mode of thought. While Fabri elaborates his full-blown theory in the theorems (which are developed assuming a void), in the preceding hypotheses we can easily discern Aristotle's "substance-centered" attitude. Discussing the final cause of motion – within hypothesis 1, which claims that "motion exists" – Fabri explains that in order that created things "could rejoice with the *bonum* which they might lack, and be joined to their goal, local motion is needed". For instance, a thirsty horse could alleviate his thirst only by moving towards water, or by having water being moved towards it; and "a stone removed from its center, its sphere, its goal (*finis*), in order to return to it, it must fall downwards".[50] Furthermore, when something reaches its goal, it wishes to stay there, for "an object connected to its *bonum* or goal does not demand to be separated from it, therefore nor to move". Fabri adds that "it would be of the greatest inconvenience for an object once moved to move perpetually", and then remarks that "the goal, or terminus of straight motion, is rest", like a stone falling downwards in order to finally come to rest in the center of the universe.[51] Fabri thus conveys a standard "anti-inertial" frame of mind, perfectly in accord with Aristotle's refusal to accept endless and resistance-less motion, i.e. what we would call "inertial motion"; according to such a conception, perpetual motion of a substance is indeed extremely "inconvenient", for it implies nothing but an unhappy existence of an object which never reaches a goal, always "searching" in vain for its *bonum*.

However, we have already noticed that within the theorems, as Fabri's concepts of motion and impetus (and the causal relationship between them) unfold, a completely different frame of mind emerges. The center of gravity moves from substance to quality: substances might "wish" to remain at rest (when they happen to be connected to their *bonum*), but the quality of impetus is given a desire of its own: it "wants" nothing but to move substances, notwithstanding their own "desires". As we shall see in Part III, the quality eventually prevails: in the absence of obstacles

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[50] "Prima duci potest a fine motus; cum enim res creatae ubique simul esse non possint, certe, ut illo bono gaudeant, quo forte carent, & ut coniungantur suo fini, motu locali opus est; sitit equus, abest aqua, certe, nisi vel haec propinetur, vel ille accedat, sitim levare non poterit; at neutrum sine motu haberi potest. Lapis removetur a suo centro, a suo globo, a suo fine, ut sese illi restituat, deorsum cadat necesse est" (Fabri 1646, lib. 1, hyp. 1, p. 3).

[51] While establishing the validity of the second hypothesis, which claims that "rest exists", Fabri says: "Non desunt rationes a priori; nam primo res aliqua suo bono, seu fini coniuncta ab eo separari non postulat, igitur nec moveri. Secundo maximum incommodum esset, si res semel mota perpetuo moveretur. Tertio, finis, seu terminus motus recti, est quies; nam ideo lapis deorsum cadit, ut in suo centro seu globo quiescat" (Fabri 1646, lib. 1, hyp. 2, p. 4).

(i.e. in a vacuum), any object once moved in a certain direction would continue to move along that direction *ad infinitum*. Part IV will describe another sort of "victory" that Fabri ascribes to his cherished impetus, this time in the field of theology: in the absence of the original substances of the bread and wine (following the process of Transubstantiation), impetus will "take over" and enable their remaining accidents to linger on without their subjects.

Having described Fabri's theory, and how it stands in relation to Aristotle's system, it remains to check to what extent his theory should be considered as a continuation of scholastic physics, or as a brand new development (perhaps inspired by the advances already brought about by the pioneers of the scientific revolution). I shall start by discussing general scholastic thought (mentioning Thomas Aquinas's view, which will be shown to be reminiscent – in some respects – to Fabri's view), and then move over to the two fourteenth century most important contributors to the theory of impetus: Franciscus of Marchia and Jean Buridan.

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Chapter 5
Fabri's Impetus and the Scholastic Tradition

It seems that in scholastic philosophy of nature, the formal cause has lost its role as an explanatory factor within the field we now call "Physics". According to Annaliese Maier, the only Aristotelian cause which played a significant part in medieval physics was the efficient cause, i.e. in the context of motion, the cause of a moving thing could only be a *motor* which moves the *mobile* by direct contact. "The formal cause", explains Maier, "was never treated as an active principle that makes things happen or changes existing conditions. Its function was merely to account for a state or mode of being." Maier even emphasizes that "formal cause has its place in the metaphysical and ontological interpretation of the world, but not in physical and dynamic explanations of nature" (Maier 1982, p. 41). Dijksterhuis also stressed the role of the Aristotelian dictum *omne quod movetur ab alio movetur*,[1] emphasizing that according to that tradition motion must be a result of a *motor*, i.e. an efficient cause:

> Aristotelian physics is based on the axiom that every motion (*motus*) presupposes a mover (*motor*): *omne quod movetur ab alio movetur*. This *motor* must either be present in the moving body or be in direct contact with it; action at a distance is excluded as inconceivable: a *motor* must always be a *motor conjucnctus*.[2]

Many other prominent historians, like Pierre Duhem, Sir David Ross, Father Peter Hoenen, Alistair C. Crombie, Marshall Clagett and William Wallace expressed a similar opinion, ultimately ascribing an "efficient causality" to Peripatetic explanations of change, or motion.[3] Patricia Reif studied (Reif 1969) late scholastic textbooks, which were written between 1600 and 1650 (i.e. Fabri's contemporaries), and reached a similar conclusion. She observes – due to what she describes as "the interplay of Aristotelian and Neoplatonic elements" – a "rather widespread tendency to reduce the substantial form of a natural body to a kind of agent", i.e. an efficient ("moving") cause (Reif 1969, p. 27). "In other words", she clarifies, "the inner

[1] Which Aristotle applies to non-living bodies, i.e. objects made of mere elements.

[2] Dijksterhuis 1961, p. 23; quoted in Weisheipl 1965, p. 31.

[3] Weisheipl 1965, pp. 30–31; Wallace 1972–1974, vol. 1, p. 170.

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formal nature of a material thing is regarded as an internal or emanative efficient cause acting upon the thing itself" (ibid.).

As we have just seen, this is exactly the interpretation adamantly rejected by Fabri, who stresses that impetus, as the formal cause of motion, is *not* an efficient cause. Are we to conclude that Fabri's standpoint is a lonely voice within the vast range of scholasticism, that he is the only philosopher within the (later) scholastic tradition who took pains to avoid the reduction of formal causality to efficient causality? James A. Weisheipl's analysis shows that such is not the case, and that Fabri was certainly not the first to refuse the abovementioned reduction (though I shall claim later – in Part III – that he indeed *was* the first scholastic thinker to use this idea in order to incorporate conservation of rectilinear motion).

5.1 Thomas Aquinas and Formal Causality

Weisheipl, in his article "The Principle *Omne quod movetur ab alio movetur* in Medieval Physics", argues that the view regarding motion as necessarily resulting from an efficient cause – e.g. a substantial form actually inhering in a subject and "pushing" it (downwards, in the case of heavy objects) – was accepted by Averroes, and was indeed influential among Latin scholastics. However, he also insists that it did not remain undisputed:

> Clearly the position attributed by modern historians[4] to Aristotle is, in fact, the position of Averroes... It cannot be denied that many Schoolmen accepted the interpretation of Averroes. In particular it was accepted by Peter of Auvergne, Godfrey of Fontaines, Peter Olivi, Duns Scotus, and the bulk of beginners' manuals popular in the fourteenth and fifteenth centuries. However, Averroes' interpretation was explicitly rejected on all essential points by St. Thomas Aquinas and to a lesser degree by Albertus Magnus and even by Siger of Brabant, the eminent founder of Latin Averroism. (Weisheipl 1965, pp. 37–38)

Weisheipl explains that "for St. Thomas the 'formal principle' of every physical being is truly an *active principle* of characteristic behavior, but not the *motor* or *principium motivum*". Otherwise, adds Weisheipl, there would not be any difference between living things which literally "move themselves" and inanimate things which obviously do not. Therefore, the efficient cause of spontaneous (inanimate) motion – e.g. a free fall of stone – cannot be its substantial form, but can only be "the agency which brought such a being into existence", i.e. the "generator" of the stone.[5] In the words of Thomas Aquinas himself, in his commentary to the *Physics*:

[4]He refers to the historians mentioned above (except Wallace).

[5]Weisheipl 1954, pp. 400–401; Weisheipl's emphasis.

> In heavy and light bodies nature is a formal principle of movement… for just as the other attributes follow upon substantial form, so too does place, and consequently motion towards place; not that the natural form is a mover, but the mover is the progenitor which produced such a form, upon which such motion follows.[6]

A formal principle, explains Weisheipl, "is simply a spontaneous source of all that comes from it naturally… Once it is brought into being, it immediately (*statim*) and spontaneously manifests characteristic behavior, unless accidentally impeded from doing what comes naturally. Thus, *qui dat formam, dat consequentia ad formam*".[7] Weisheipl emphasizes again and again that "For Aristotle as well as for St. Thomas" – though, as have seen, not according to Averroes' interpretation – "the form is *not the mover*, but the *source* of necessary and spontaneous movement".[8] It seems to me that Thomas's explicit reference to a "formal principle of movement", which is not the real (i.e. efficient) mover of a naturally moving object (e.g. a falling stone) could be considered as a kind of inspiration to Fabri's universal and unequivocal definition of impetus as a formal and not efficient cause of motion. In any case, Fabri's own discussion on free fall (presented in Part II) will show that he was fully aware of inner "active principles" of natural movement within Aristotle's and Thomas's explanations, though the adjective "formal" does not appear in Fabri's description of this Peripatetic tradition. It is worth mentioning that in the influential commentary to the *Physics* by the Jesuit *Collegium Conimbricenses*, written in 1594, it is also clearly stated that (according to Aristotle) naturally moving objects do not have in themselves the efficient cause of their motions.[9]

Weisheipl has successfully shown that unlike the situation many historians (especially Maier) seem to portray, there was no consensus among scholastics concerning the reduction of formal causality to efficient causality (even if many – probably even most – philosophers did resort to such a reduction, as Maier and Reif have shown). Furthermore, Aquinas's actual use of the notion *principium formale* might suggest that Fabri's attitude should not be seen as appearing "out of the blue", even if Thomas did not directly influence Fabri in this matter.[10] However,

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[6]"In corporibus vero gravibus et levibus est principium formale sui motus… quia sicut alia accidentia consequuntur formam substantialem, ita et locus, et per consequens moveri ad locum: non tamen ita quod forma naturalis sit motor, sed motor est generans, quod dat talem formam, ad quam talis motus consequitur" (Thomas Aquinas, *In 2 Phys.*, 1, n. 4; quoted in Weisheipl 1954, p. 401, n. 78).

[7]Weisheipl 1965, p. 39. The quote is from *In 3 De Caelo*, lect. 7, n. 8; Weisheipl remarks (in note 59) that the quoted principle "is found throughout St. Thomas's writings on the subject".

[8]Weisheipl 1954, p. 403 (his emphasis). As for Aristotle's view of "actualizing potentialities", which indeed does not consider the form to be an "efficient" mover, see Section 7.2 below.

[9]Conimbricenses 1594, lib. 8, cap. 4, p. 298: "Vult ergo Aristoteles gravia et levia cum in propria loca feruntur ab eodem deduci per se ad eiusmodi actum secundum ex potestate proxima, a quo ex potestate remota ducuntur ad actum primum, hoc est a suo generante, nec habere in se ipsis principem causam efficientem horum motuum".

[10]As I have just indicated, there is no textual link which would imply such a direct influence. Fabri himself does not specify Aquinas – or any one else, for that matter – as a possible "inspiration" to his concept of impetus as a formal and non-efficient cause.

we must not overemphasize the affinity between these conceptions: for Thomas explicitly restricts his idea of a *principium formale* of motion to "spontaneous" – i.e. natural – motion. According to thirteenth century scholasticism (in this case – including Thomas), violent motion cannot be accounted for by any internal, intrinsic factor.[11]

The need for an external mover in violent motion is indeed a very important principle in basic Aristotelian thought, and it can safely be claimed that in this matter there was a full consensus among scholastic thinkers. We have already encountered (in Chapter 1 above) Aristotle's definition of "nature" as a principle necessarily inhering "primarily" (i.e. essentially) inside things: "a source or cause of being moved and of being at rest in that to which it belongs primarily". In violent motion, however, there is nothing "natural" involved, therefore by definition neither anything intrinsic: "The fact that a thing that is in motion derives its motion from something is most evident in things that are in motion unnaturally, because in such cases it is clear that the motion is derived from something other than the thing itself".[12] It is no wonder that in explaining the continuance of projectile motion, Aristotle resorted to the medium surrounding the moving projectile; as a "paradigm" of violent motion, it would be inconceivable to suppose that it could arise from a source inhering inside it. In fact, the external character of any violent action is deeply rooted in Aristotle's basic moral views, displaying the well known affinity between the realms of physics and ethics in his thinking. In the third book of *Nicomachean Ethics* Aristotle claims that "those things, then, are thought involuntary, which take place under compulsion or owing to ignorance; and that is compulsory of which the moving principle is outside, being a principle in which nothing is contributed by the person who is acting or is feeling the passion [i.e. affection], e.g. if he were to be carried somewhere by a wind, or by men who had him in their power".[13] Thomas indeed claims that a stone moving violently cannot do so by an impressed force (*virtus*) of any kind, otherwise we would have to admit that violent motion arises from an "intrinsic principle", which is against the doctrine, or logic (*ratio*) of violent motion.[14] Similarly, as Margaret Osler emphasized, scholastic natural philosophy closely related finality with natural processes, and systematically rejected any purposefulness within violent ones: "In natural substances and processes, the final cause was considered to be immanent, an aspect of the nature of the thing that caused it to actuate its form",

[11] Weisheipl 1955, p. 57, n. 28.

[12] *Physics* [Aristotle 1930], 8, 4, 254b24–27. Aristotle defends here his dictum *omne quod movetur ab alio movetur*. In applying it to "natural" motions Aristotle of course encounters difficulties (from which contrary interpretations like those of Averroes and Thomas could have – and indeed have – arisen), but in applying it to violent motion Aristotle can afford to appear utterly decisive.

[13] *Nicomachean Ethics* [Aristotle 1966], 3, 1, 1009b35–1110a3.

[14] "Non est autem intelligendum quod virtus violenti motoris imprimat lapidi qui per violentiam movetur, aliquam virtutem per quam moveatur, sicut virtus generantis imprimit genito formam, quam consequitur motus naturalis; *nam sic motus violentus esset a principio intrinseco, quod est contra rationem motus violenti*" (Thomas Aquinas, *In 3 De Caelo*, lect. 7. n. 6; original text copied from Weisheipl 1955, p. 57. n. 28; Weisheipl's emphasis).

while "accidental or unnatural processes – such as the rising of a heavy body or the birth of deformed offspring – lack finality and accordingly are not natural" (Osler 2001, p. 153).

In Thomas's theory then – in accordance with general scholastic philosophy – we are still very far from Fabri's conception of projectile motion (or any other violent motion) as "the inner goal of impetus", which in the absence of any hindrance to motion would "rejoice in its goal" (Section 4.3 above). However, advances towards Fabri's view of a formal causality of motion (violent and natural alike) – in which an increasing attention is paid not to the subject, or substance (i.e. the moving body) but to the purported accidental form causing its motion (*virtus* or *impetus*), and in which projectile motion is no longer considered entirely "violent" – could indeed be found in fourteenth century thought. I shall now discuss the theories of projectiles suggested by Franciscus of Marchia and Jean Buridan and concentrate on these important aspects (the central issue of Buridan's free fall theory will be discussed in Part II).

5.2 Franciscus Marchia and the *vis derelicta*

The first in the Late Medieval West to advocate an entity, or "force" (*virtus*), responsible for the continuing motion of a projectile after being projected was Franciscus of Marchia (Maier 1982, p. 85). Marchia seems highly important for our understanding of Fabri's notion of impetus not only because of this reason, but also owing to the context in which he presented the problem of the projectile. In his 1323 commentary on Peter Lombard's *Sentences*, Marchia asks "whether in the Sacraments some supernatural force (*virtus supernaturalis*) exists which formally inheres or persists (*insistens*) inside them"; his ultimate answer, by the way, is that such a force need not be assumed.[15] As an analogy to the alleged persistent *virtus* which conserves the Divine Grace bestowed by the priest during the "Sacraments", Marchia immediately suggests a kind of force[16] that apparently dwells in the projectile after it leaves the hand of the projector. As we shall see in Part IV Fabri will also connect the

[15] "Utrum in sacramentis sit aliqua virtus supernaturalis insistens sive eis formaliter inhaerens"; Annaliese Maier 1951, pp. 166, ll. 1–2. The original Latin text can be found in Maier 1951, pp. 166–180; a partial translation to English in Clagett 1959, pp. 526–530. Ultimately Marchia concludes that in the sacraments, after all, there does not exist any "persisting" or "inhering" *virtus*, and God directly acts to produce their effects ("Quantum ad tertium articulum dico, quod in sacramentis non est aliqua virtus insistens sive eis inhaerens formaliter, sed tantum est in eis virtus subsistens, quae Deus est, qui immediate agit ad effectum cuiuslibet sacramenti"; Maier 1951, p. 180, ll. 494–497).

[16] The translation "force" might be misleading, because (as will soon be apparent) by the term *virtus* Marchia means a *form* which is "inserted" into the stone after leaving the thrower's hand. Antonio Moreno explains that "in philosophy *virtus* signifies a quality which retains the power for action of the principal agent", and this is why he consistently translates *virtus* as "power" (Moreno 1974, p. 326). However, considering that Marchia depicts the force of the throwing hand itself also as a *virtus*, there is no reason not to follow Clagett's translation for *virtus* – "force" – while warning the reader not to understand it as a mechanical (let alone Newtonian) concept.

notion of impetus to the most important sacrament – the Eucharist – and in a much more drastic manner than the humble analogy offered (and ultimately rejected) by Marchia.

Marchia therefore discusses the reason responsible for the motion of an object thrown upwards. After rejecting several possible candidates – the throwing hand (which could be destroyed immediately after throwing the projectile, without affecting the upward motion), the form of the projectile (which could only be responsible for natural and "determined" motion, while projectile motion is violent and could occur along any direction), the medium, the thrown object itself and a celestial form – he finally reaches the preferred cause: the "last affirmative conclusion, which follows out of the aforementioned, is that motion of this kind arises immediately from some force left behind (*virtus derelicta*) by means of an initial action of the first motor, for example, a hand".[17]

Now Franciscus discusses whether this "force" resides in the medium, as the *Philosophus* (Aristotle) and the *Commentator* (Averroes) claim, or in the moving body itself. Franciscus, unlike Buridan and Fabri after him, does not deny that the medium is partly responsible for the continuing movement of the projectile: he actually states that a *virtus derelicta* is also left in the medium and contributes to the motion (Clagett 1959, pp. 529–530). As Clagett explains, this "conciliatory" opinion had a great influence in the following centuries: "many authors in the course of the fourteenth, fifteenth and sixteenth centuries accepted a supplementary role for the air in causing the continuance of the projectile motion, no doubt with the object of 'saving' Aristotle" (ibid., p. 551). However, Marchia argues that this force resides firstly, or mainly, in the moving object, and only then in the medium.[18] One of the reasons he presents in favor of this opinion reveals the way in which this force is initially created. Marchia explains that the stone receives the motion of the throwing hand before the air, and therefore the stone also receives "the form which is the terminus of the motion" (i.e. the *virtus derelicta*) before the air: "the hand does not move the air without moving the stone, therefore the stone receives the motion of the hand before the air does and consequently [also] this kind of force left behind by the motion (*virtus huiusmodi derelicta per motum*)".[19]

[17] Clagett 1959, p. 527 (his translation). "Et ultima conclusio affirmativa, quae sequitur ex praedictis, est, quod huiusmodi motus est immediate ab aliqua virtute per modum actus primi derelicta ab ipso primo motore, puta a manu" (Maier 1951, pp. 168, ll. 186–188).

[18] "... arguo et ostendo, quod huiusmodi virtus prius sit in lapide vel in quocumque alio gravi moto, quam in medio" (Maier 1951, pp. 170, ll. 155–157).

[19] "Praeterea illud quod primo est suspectivum effectus sive motus moventis prius est suspectivum formae causatae per illum, quod enim est respectivum motus et formae quae est terminus motus: sed lapis prius quam aer est suspectivus motus localis per quem causatur huiusmodi virtus a motore, ergo et istius virtutis derelictae per motum ipsum. Probatio medii, quia manus non movet aerem nisi movendo lapidem, ergo lapis prius recipit motum manus quam aer et per consequens virtutem huiusmodi derelictam per motum, cum sit capax eius, ut ostensum est. Quod autem virtus huiusmodi causetur per motum sive ipso mediante patet, cum manus quiescens sicut nec movet aliquid ita nec causat aliquid in aliquo, puta lapide in aere" (Maier 1951, p. 171, ll. 184–195).

The *virtus derelicta* creating mechanism, which involves the motion of the throwing hand (prior to the separation of the projected stone from the projected hand) described by Marchia is of course reminiscent of Fabri's "first type of motion", regarded by the Jesuit as an "action" by which the motive force "acts and produces impetus" (*actio, qua revera agit, producitque impetum*; see Section 4.3 above). Indeed, Marchia's subsequent analysis shows another similarity between Fabri and his Franciscan predecessor:

> Whence it is to be known that the force moving some heavy body upward is twofold: [1] one which begins the motion or determines the heavy body for some motion – and this force is the force of the hand; [2] another force which follows (*exequens*) the motion after it has begun and continues it – and this is caused or left behind by the first [force] by motion (*per motum*). For unless some force other than the first one is posited, it is impossible to give a cause for the succeeding motion, as was deduced above.[20]

So Marchia, like Fabri, distinguishes between these two stages of projectile motion, and even claims – like Fabri – that the form which continues the motion (*virtus derelicta* in Marchia's case and impetus in Fabri's) is caused by the motion of the "first type". But the more interesting stage of motion is no doubt the "second type", i.e. the un-Aristotelian and non-trivial one, occurring after the stone has left the thrower. How does Marchia characterize the causality existing between the *virtus derelicta* and the continuing projectile motion? Scholars strongly disagree with regard to this interesting question. Maier sees in Marchia's theory a standard Aristotelian explanation, apart from substituting the projectile for the medium as the subject of transmitted force, which gradually decreases until the projectile is no longer moved by it; "otherwise, Marchia's description of this force is entirely consistent with Aristotle's ideas" (Maier 1982, pp. 85–86). Since we are dealing here with violent motion, such a view must consider the causality between Marchia's *virtus derelicta* and the resulting motion as entirely "efficient".[21] James Weisheipl, however, holds a totally different opinion. "Marchia", he claims, "did not conceive this *virtus derelicta* in projectiles and in the sacraments as *motores coniuncti*, but simply as instrumental powers separated from the true cause which conferred the *virtus*" (Weisheipl 1965, p. 44).

What does Marchia himself say about the manner in which his *virtus derelicta* causes motion? Not much, actually. "This force," he claims, "regardless of which subject it is posited as being in, continues and follows (*continuat et exequitur*)

[20]Clagett 1959, pp. 528–529. "Unde est sciendum, quod est duplex virtus movens aliquod grave sursum, quaedam motum incohans sive grave ad motum aliquem determinans et ista virtus est virtus manus; alia virtus est motum exequens incohatum et ipsum continuans et ista est causata sive derelicta per motum a prima. Nisi enim ponatur aliqua alia virtus a prima, impossibile est dare causam motus sequentis, ut superius est deductum" (Maier 1951, p. 172, ll. 225–232). I have somewhat revised Clagett's translation. I translated *exequens* as "follows" instead of "comes after", and *per motum* as "by motion" instead of "with the object of producing motion".

[21]We have already seen that Thomas Aquinas, *pace* Averroes, regards *natural* motion as caused by a "formal principle", but both – together with Aristotle, of course – agree that *violent* motion must result from an external mover (the medium).

the motion according to the proportion and mode determined by the first [force]". The *virtus derelicta* then merely "continues" the motion already created in the first "stage", or "type" of motion; it "follows" the motion, since it is indeed – as we have just seen – created "*per motum*". Furthermore, Marchia immediately adds that "this is a neutral force not having a contrary, since it follows motion according to any difference of position".[22]

Weisheipl is perfectly justified therefore in claiming that this *virtus* is no more than an "instrumental power" continuing the motion conferred by the thrower, rather than a "full-blown" efficient cause which (in Fabri's terms) would produce motion. Marchia would have probably agreed with Weisheipl (*pace* Maier) that this *virtus* – as merely "following" motion – cannot be considered a real *motor coniunctus*, but in light of the brevity of his discussion on this subject we cannot escape the impression that this issue was not very important to him. Marchia's description of his *virtus derelicta* as a "neutral" form – devoid of any contrary – enhances our impression that it is quite a "modest" concept, totally dependent on the projecting force; elsewhere Marchia emphasizes that the projectile's motion "is determined according to every difference of position, for it can move forward and in reverse, from the right and from the left, by circular motion and by straight motion, therefore etc."[23] Marchia's "obedient" and "submissive" *virtus derelicta* is indeed a far cry from Fabri's autonomous and totally self-sufficient impetus, which "rejoices" in motion and exerts movement in straight lines whatever the identity or disposition of the original moving force. Also unlike Fabri's (and Burdian's) permanent impetus, Marchia's *virtus derelicta* "is not simply permanent nor simply fluent, but almost medial [between them], since it lasts (i.e., is permanent) for a certain time".[24] It can therefore be seen as a "self expending" force, i.e. a force which does not need any obstructing factor for gradually decreasing. As we have seen, it is a "neutral force", unaffected by other forces but inherently self-dissipating, very different indeed from Buridan's and Fabri's permanent quality of impetus.

Before moving on to Buridan's theory, it is worth discussing another important remark made by Marchia, while addressing arguments supporting Aristotle's opinion that the moving force resides in the medium. One of them is that

> Every motion which arises from an intrinsic source is natural. For nature is the source (*principium*) of motion and rest, according to the Philosopher in the second [book] of the *Physics*.[25] But the motion of a stone upwards is not natural but violent. However, if it were to rise from some force received in the stone, it would be natural because it would arise

[22]Clagett 1959, p. 529; his translation ("ista virtus in quocumque subiecto ponatur continuat et exequitur motum secundum proportionem et modum quo determinata est a prima, et ista est virtus neutra non habens contrarium, cum exequatur motum secundum omnem differentiam positionis"; Maier 1951, p. 172, ll. 232–236).

[23]". . . iste motus est determinatus ad omnem differentiam positionis, potest enim moveri ante et retro, a dextris et a sinistris, motu circulari et motu recto, ergo etc." (Maier 1951, p. 167, ll. 60–63).

[24]Clagett 1959, p. 529; his translation ("nec est forma simpliciter permanens nec simpliciter fluens, sed quasi media, quia per aliquod tempus permanens"; Maier 1951, pp. 172–173, ll. 237–238).

[25]*Physics* [Aristotle 1930], 2, 1, 192b23.

> from an intrinsic source in the moving body; therefore etc. Besides, according to the third book of the Philosopher's *Ethics*,[26] a principle of [something] violent arises from outside and it does not confer to the affected object (*passus*) any force (*vis*), therefore while moving a heavy object upwards it confers no force to the affected object, namely to the moving stone, therefore the mover does not imprint or cause any force (*virtus*) in it, but rather in the medium.[27]

This is exactly the argument raised by Thomas, described above (including the references within Aristotle's works mentioned here by Marchia). Marchia's subsequent answer might be seen as somewhat approaching Fabri's fully developed attitude which completely transfers attention from "substance" to "quality": Marchia explains that this kind of motion should indeed be considered *violent* from the point of view of the "natural virtue of the stone", "since it is contrary to its natural inclination", but it is nevertheless "*somehow connatural*" in regard to the stone's "accidental virtue, left behind extrinsically by the original force". Marchia concludes that "the motion is violent, because [it is] against the inclination of the natural form, and [is also] in accordance with what is natural, since [it is] in accordance with an inclination of an accidental form".[28] So projectile motion *can* be caused by an accidental form inhering inside the moving body, and thus somewhat "loses" its violent character: it is still considered violent regarding the "substance", but it is "somehow connatural" from the point of view of the "quality" (or "accidental form", in Marchia's case).

At any rate, Marchia's subsequent analysis shows that he is still far from Fabri's view: he emphasizes that the throwing hand confers on the moving object not a "natural or intrinsic" force, but an "alien and opposing (*disconveniens et repugnans*)" extrinsic accident, and even proposes that this violent motion involves losing a natural inclination rather than gaining any "positive" essence by the throwing agent.[29] The emphasis in Marchia's analysis clearly still lies very much in the moving substance, not in the accident that conserves (only temporarily, even without impediments) its initial motion.

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[26] *Nicomachean Ethics* [Aristotle 1966], 3, 1, 1110a1.

[27] Clagett 1959, p. 528, his translation, except for the last sentence ("omnis motus, qui est a principio intrinseco, est naturalis, natura enim est principium motus et quietis secundum Philosophum 2^0 Physicorum, sed motus lapidis sursum non est naturalis sed violentus, sed si esset a virtute aliqua recepta in lapide esset naturalis, quia esset a principio intrinseco mobilis, ergo etc. Praeterea secundum Pholosophum 3^0 Ethicorum violentum est cuius principium est extra non conferens passo aliquam vim, ergo movens grave sursum nullam vim confert passo, videl. lapidi moto, ergo nec aliquam virtutem influit sive causat in ipso, sed in medio"; Maier 1951, p. 170, ll. 140–149).

[28] "Ad secundam, quando dicitur quod omnis motus est naturalis etc., dico quod motus iste potest comparari vel ad virtutem naturalem lapidis et sic est violentus, cum sit contra eius inclinitanionem naturalem, vel ad virtutem eius accidentalem et extrinsecam derelictam a prima virtute, et isto modo est aliquomodo connaturalis. Et ita ut simpliciter motus violentus, quia contra inclinationem formae naturalis, et secundum quid naturalis, quia secundum inclinationem formae accidentalis" (Maier 1951, p. 175, ll. 313–320).

[29] "Movens enim sive agens non confert ipsi mobili passo vim [sive] perfectionem aliquam naturalem sive intrinsecam, nec etiam confert vim sive perfectionem aliquam accidentalem et extrensicam sibi convenientem, sed disconvenientem et repugnantem. Et ideo non dicitur aliquid

5.3 Jean Buridan and the Permanent Impetus

Buridan was the first to use the name "impetus" for defining the inherent "force" moving the projectile or falling body. His basic concept of impetus is described in the following lines cited from his *Questions on the Physics*:

> In the stone or other projectile there is impressed something which is the motive force (*virtus motiva*) of that projectile... the motor in moving a moving body impresses (*imprimit*) in it a certain impetus (*impetus*) or a certain motive force (*vis motiva*) of the moving body, [which impetus acts] in the direction toward which the mover was moving the moving body, either up or down, or laterally, or circularly...
>
> Impetus is a thing of permanent nature (*res naturae permanentis*), distinct from the local motion in which the projectile is moved ...and it is probable that that impetus is a quality naturally present and predisposed for moving a body in which it is impressed, just as it is said that a quality impressed in iron by a magnet moves the iron to the magnet. And it is also probable that just as that quality (the impetus) is impressed in the moving body along with motion by the motor; so with the motion it is remitted, corrupted, or impeded by resistance or a contrary motion.[30]

We can immediately see that although Buridan defines impetus as a "quality", he still refers to it also as a *virtus motiva*, or *vis motiva*: unlike Marchia before him and Fabri after him, he does not distinguish (neither in this paragraph, nor anywhere else – as far as I can tell) between two "stages" of projectile motion, and perhaps consequently blurs the difference between "motive force" and "impetus". Furthermore, despite his claim that impetus is "distinct from local motion", unlike Fabri he does not clearly distinguish between the two. This is apparent in the way he describes the decay of motion, in which the impetus "with the motion is remitted, corrupted, or impeded"; it seems that for him impetus depends on motion no less than motion depends on impetus. It is also important to notice (in the quoted passage) that like Fabri – and unlike Marchia – Buridan opts for a totally permanent impetus, i.e. destroyed only by contrary factors (gravity, friction, air resistance etc.).

Having presented the notion of impetus, Buridan raises two "not unimportant difficulties (*difficultates non parvae*)" concerning it. His answers to them will reveal

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sibi conferre, sed magis dispositionem sibi convenientem auferre, dando enim quod sibi disconveniens est et contra eius naturalem inclinationem aufert quod conveniens est. Et ideo dicitur nihil sibi conferre" (Maier 1951, p. 175, ll. 336–343).

[30]Clagett 1959, pp. 534, 537; his translation and parenthetical enclosures (most of them presenting the Latin terminology): "ita possumus et debemus dicere quod lapidi vel alteri proiecto imprimitur talis res, quae est virtus motiva illius proiecti... Ideo videtur mihi dicendum, quod motor movendo mobile imprimit sibi quendam impetum vel quandam vim motivam illius mobilis ad illam partem ad quam motor movebat ipsum, sive sursum sive deorsum sive lateraliter vel circulariter" (Maier 1951, pp. 210–211, ll. 119–127); "ille impetus est res naturae permanentis, distincta a motu locali, quo illud proiectum movetur... Et verisimile est, quod ille impetus est una qualitas innata movere corpus, cui impressa est, sicut dicitur quod qualitas impressa ferro a magnete movet ferrum ad magnetem. Et etiam verisimile est, quod sicut illa qualitas mobili cum motu imprimitur a motore, ita ispa a resistentia vel inclinatione contraria remittitur, corrumpitur vel impeditur sicut et motus" (Maier 1951, pp. 213–214, ll. 227–235). Buridan's Latin text (taken from Buridan 1509) is reproduced in Maier 1951, pp. 207–214.

his view regarding the causality he advocates between impetus and motion and the extent to which he emphasizes this quality (rather than the moving substance). "The first difficulty", writes Buridan, "arises because according to what has been said a stone projected upwards moves by an intrinsic principle – namely, by the impetus impressed in it – and this does not seem true, because that impetus is conceded by everyone to be violent, however that which is violent does not arise from an intrinsic active principle, but from an extrinsic one, as it is claimed in the third book of *Nicomachean Ethics*".[31] The second difficulty simply concerns the nature of the impetus: what kind of a thing is it, asks Buridan; is it "motion itself or something else?"[32] Here is Buridan's reply to the first "difficulty":

> Concerning the first difficulty it may be said that a heavy projectile indeed moves up by an intrinsic principle inhering in it, and nevertheless it is said to move violently, because that principle – namely, that impetus – is violent and unnatural, because it disagrees with its formal nature (*suae naturae formali disvonveniens*) and has been impressed violently by an external principal, and because the nature of gravity itself inclines to an opposite motion and to corrupt that very impetus.[33]

Marchia (see Section 5.2 above) regards projectile motion as violent from the standpoint of the stone, but "connatural" as far as the accidental form of *virtus derelicta* is concerned. Buridan thinks that this motion arises from the impetus as an "intrinsic principal", but emphasizes that from the point of view of the moving object it is "violent and unnatural", since it "disagrees" with the object's "formal nature". Thus Buridan, like Marchia, does not ignore the "intrinsic" aspect of impetus (though unlike the latter he does not describe motion as "connatural" to it), but still stresses its "violent" aspect, i.e. the point of view of the substance rather than that of the quality responsible for its motion. Buridan's view, like Marchia's, is far from Fabri's conception of an "emancipated" impetus formally causing – while independently "rejoicing" in – the motion of the substance in which it resides.

In his dissertation dedicated to Fabri's theory of motion, *An Aristotelian Response to Galileo: Honoré Fabri, S.J. (1608–1688) on the Causal Analysis of Motion*, David Lukens claims the contrary. He argues that according to Buridan, "the impetus which the thrower impresses on the mobile is called 'a violent *formal*

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[31] "Sed tamen circa hac opinionem sunt difficultates non parvae. Prima difficultas est quia secundum dicta lapis proiectus sursum movetur a principio intrinseco, scil. ab illo impetu sibi impresso, et hoc non videtur esse verum, quia ille motus ab omnibus conceditur esse violentus, et tamen violentum non est a principio activo intrinseco, sed extrinseco, ut habetur tertio Ethicorum" (Maier 1951, p. 212, ll. 185–191); cf. Marchia's account (Section 5.2 above) and Thomas's explanation (Section 5.1).

[32] "Secunda difficultas est quae res sit ille impetus? Utrum vero sit ipsemet motus vel alia res?" (Maier 1951, p. 212, ll. 191–192).

[33] "Ad primam difficultatem potest dici, quod grave proiectum sursum bene movetur a principio intrinseco sibi inhaerente, et tamen dicitur moveri violenter, ex eo quod illud principium, scil. ille impetus, est sibi violentus et innaturalis, quia suae naturae formali disconveniens et a principio extrinseco violenter impressus, et quod natura ipsius gravis inclinat ad motum oppositum et ad corruptionem ipsius impetus" (Maier 1951, p. 213, ll. 196–202).

principal of motion' ".[34] As the source of this "quotation", Lukens points[35] exactly to the passage just quoted here, in which the only instance of the adjective "formal" occurs when Buridan describes the impetus as *disagreeing* with the "formal nature" of the stone (*suae naturae formali disconveniens*). How did Lukens infer from these lines that Buridan considered impetus itself as a "formal principal"? I have no answer to this question. Lukens immediately concludes that "the impetus is thus excluded as an efficient cause of projectile motion and (as will be seen) is made a *formal* cause",[36] thus depicting – without any textual evidence (in fact, against the existing text) – Buridan as Fabri's precursor in this important point. Furthermore, soon afterwards, Lukens claims that according to Buridan "impetus *formally* causes (*facit*) the body to be in local motion",[37] while the adverb *formaliter* does not exist at all in the text Lukens is referring to: Buridan simply says there that "*ille impetus facit illum motum*". This text – which not only refutes Lukens's claim but also reveals Buridan's real opinion on this important matter – is included in Buridan's response to the second "difficulty" (concerning the nature of impetus):

> The first [conclusion] is that impetus is not the very local motion in which the projectile is moved, because that impetus moves the projectile and the mover creates (*facit*) motion. Therefore, the impetus creates that motion, and the same thing cannot create itself. Therefore, etc. Also since *every motion arises from a motor being present and existing simultaneously with that which is moved*, if the impetus were the motion, it would be necessary to assign some other motor from which that motion would arise. And the principal difficulty would return. Hence there would be no gain in positing such an impetus.[38]

This passage is highly important not only in the context of Lukens's attempt to ascribe to Buridan the concept of impetus as a formal cause, but also in order to evaluate Weisheipl's position on this matter. We have already seen how Weisheipl convincingly demonstrates that according to Thomas Aquinas *natural* motion arises from an inner formal principle and not from an external mover acting as an efficient cause; furthermore, Weisheipl's assertion that Marchia regarded *virtus derelicta* responsible for *violent* motion as an "instrumental power" and not a *motor coniunctus* has been shown to be quite consistent with Marchia's text. Concerning Buridan, Weisheipl claims that his view is very similar to Marchia's: "Like de Marchia he insisted that the impetus given to a projectile is violent, unnatural, extrinsic in its

[34] Lukens 1979, pp. 72–73; my emphasis.

[35] Lukens 1979, p. 73, n. 67.

[36] Lukens 1979, p. 73; my emphasis.

[37] Lukens 1979, p. 74; my emphasis.

[38] Clagett 1959, p. 536; his translation (except for the word "*facit*", which Clagett translated as "produces", while due to Fabri's sensitivity I preferred the translation "creates"); emphasis mine. "Prima est quod ille impetus non est ille motus localis, quo proiectum movetur, quia ille impetus movet proiectum, et movens facit motum, igitur ille impetus facit illum motum, et idem non facit seipsum, ergo etc. Item cum omnis motus sit a motore praesente et simul existente cum eo, quod movetur, si ille impetus esset motus, oporteret assignare motorem alium a quo esset ille motus et reverteretur principalis difficultas. Ideo nihil proficeret ponere talem impetum" (Maier 1951, p. 213, ll. 204–212).

nature… Similarly, Buridan did not conceive impetus as a *motor coiniunctus*, but simply as a vehicle by which the mover achieves his goal" (Weisheipl 1965, p. 44). But we have just seen that according to Buridan, impetus is actually an intrinsic principle, despite being violent. Furthermore, remembering that Buridan was a staunch supporter of the *fluxus formae* opinion, which considered motion as a full-blown entity (as opposed to Fabri's view, regarding it as a non-entity), we should be suspicious towards Weisheipl's claim that Buridan did not see the impetus as a *motor coniunctus*. As far as I can tell, Buridan nowhere states explicitly that impetus is a *motor coniunctus*. However, the line I emphasized in the passage just quoted – claiming that "*omnis motus est a motore praesente et simul existente cum eo, quod movetur*" – seems to remove any doubt that this is indeed what he believes.

We are facing quite an ironic situation. There is of course no trace of "inertial" thinking in Thomas's theory of motion, nor in Marchia's account (his *virtus derelicta* is totally "self expending", therefore not allowing for any conservation of motion even in the absence of any impediment). Buridan's impetus, however – might be considered (and indeed occasionally was, e.g. by Pierre Duhem) as linked to the modern idea of conservation of motion, because it is entirely permanent and is diminished only by inhibiting factors; furthermore, as a "permanent quality" its ontological status seems close to the one Fabri ascribes to his notion of impetus. Yet, Fabri's theory – which, as will be shown below, is nothing but an attempt to fully incorporate the idea of conservation of rectilinear motion – could have been influenced (concerning the issue of "impetus-motion causality") by Thomas and Marchia, but in no way (*pace* Lukens) by Buridan, who evidently saw impetus as a *motor coniunctus*! The "irony" just mentioned is in fact imaginary. It arises from searching within old theories of historical figures modern notions that are totally alien to the general frames – or paradigms – in which those historical figures were working. The modern notion of conservation of rectilinear motion is of course totally alien to Thomas's and Marchia's thought – there is surely no need to dwell on this point. It is also alien in regard to Buridan, who rejected the possibility of motion in the void (see beginning of Chapter 14 below). Fabri's "paradigm", however – as will be shown in the following two parts – is very different from his scholastic predecessors.

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Part II
Natural Motion

Chapter 6
Fabri and the "Second Galilean Affair"

The issue of free fall – natural motion downwards – occupied an especially important place during the 1640s, the years when Fabri taught natural philosophy (among other subjects) in the Jesuit college at Lyon. It is no wonder that immediately after the first book of Fabri's *Tractatus physicus de motu locali* (i.e. *De impetu*) – presenting the essentials of the key concept of impetus – appears the second book, *De motu naturali deorsum*, which is significantly bigger than any other book within Fabri's *Tractatus* (except for *De impetu* itself, the biggest among the ten books). Galileo's new observations and ideas, wandering across Europe since the publication of the *Two New Sciences* (1638), rocked the foundations of the accepted Aristotelian way of thinking concerning natural motion, and Fabri's response to Galileo's innovations is one of the most impressive manifestations of this phenomenon. As we shall see, Fabri wholeheartedly accepted Galileo's experimental results, as well as the Pisan's key principles of the simple proportionality between velocity of time ($v \propto t$) and the universal speed of falling bodies (in the void), and also embraced Galileo's Archimedean "infrastructure" which lies behind his philosophy of natural motion (i.e. the abolition of levity). However, loyal to his general physical scheme of reducing "natural effects" to their causes, and true to his more specific intention to reduce motion to impetus,[1] Fabri could not accept Galileo's conscious (even though ad hoc) refusal to identify a cause for natural motion. Furthermore, Fabri also refused to accept Galileo's revolutionary assumptions (highly disputed by contemporaries) concerning the structure of the continuum and the behavior of infinite series; therefore Fabri developed an alternative mathematical analysis (a discrete one, contrary to Galileo's continuous approach), and consequently proved its perfect convergence to Galileo's results under the assumption of extremely small instants. This part will examine Fabri's attempt to incorporate the essentials of Galileo's theory of falling bodies, by apparently using the traditional (and thus legitimate) concept of impetus,[2] while harshly criticizing Aristotle's notions concerning this important subject.

[1] See beginning of Chapter 1 and also Section 4.2 above.

[2] As was explained in Part I – and will be further clarified in Parts II and III – Fabri's concept of impetus in fact differs substantially from any "traditional" version of it.

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Galileo's greatest achievement – the formulation and experimental verification of a mathematical law of fall, outlined in his celebrated *Two New Sciences* – prepared the setting which gave rise to competing subsequent theories of free fall, including Fabri's version, the subject of this part. This historical setting is described by Paolo Galluzzi, in his article "Gassendi and *l'affaire Galilée*" (Galluzzi 2001, pp. 239–275). Pierre Gassendi, in his *De motu impresso a motore translato* (1642), was the first to comment on Galileo's theory and to clearly lay out the fundamentals of these intensive discussions, coined by Galluzzi "the second Galilean affair" (the first one being, of course, the sequence of events which ended in Galileo's 1633 condemnation). But it was Marin Mersenne – the indefatigable coordinator of the lively correspondence within the scientific Republic of Letters – who functioned (until his death in 1648) as "the active and able director" of the international controversy around Galileo's new theory of falling bodies. As Galluzzi informs us,

> In France, thanks to Mersenne and to his epistolary network, the Jesuits Pierre Le Cazre and Honoré Fabri were involved in the *affaire*, as well as Boulliau, Roberval, Le Tenneur and, more marginally, Descartes and Pierre Fermat. In Holland, the solicitations of Mersenne caused the intervention of the *enfant prodige* Christian Huygens, who would give eloquent proof of his own mathematical talent. Lastly, during his journey to Italy between the end of 1644 and the first months of 1645, Mersenne succeeded in involving in these discussions Evangelista Torricelli and Michelangelo Ricci. Moreover, after his return to France, he kept an intense epistolary exchange on these same topics with Galileo's disciples in Florence and Rome, as well as with the Genoese Giovan Battista Baliani (Galluzzi 2001, pp. 239–240).

Fabri's complicated attitude towards Galileo's heritage may be discerned in the following passage, taken from the beginning of the preface to the *Tractatus*:

> Many have fruitfully exerted themselves until now in this matter. Indeed the Great Galileo, who before any one else wonderfully and with almost divine sharpness of genius led local motion to where no mortal had led it before; nevertheless because he omitted many things that relate to motion, as everyone knows, and did not prove those marvelous effects from physical principles, but only assented to some proportions from geometrical [principles]; in order to have regard for physics, we undertake another way: we do consult geometry, to explain and set forth those aforementioned proportions which belong to motions; but we reduce the effects connected to those proportions to physical principles; in other words, while we suppose *what* there is (*quod sint*), we prove *why* it is (*propter quid sint*).[3]

Fabri, summarizing here the achievements and shortcomings of the "Great Galileo", refers first and foremost to Galileo's "mathematical" theory of free fall. Galileo's most substantial contribution to the science of motion – which, in Fabri's

[3] "Multi sane hactenus in hac materia feliciter desudarunt; & quidem prae caeteris magnus ille Galileus, qui mirifica, & fere divina ingeni iacie, motum localem eo perduxit, quo mortalium nemo perduxerat; quia tamen multa omisit, quae ad motum spectant, ut nemo nescit; nec ex principiis Physicis mirabiles illos effectus demonstravit, sed tantum certis quibusdam proportionibus ex geometricis addixit; ut Physicae consulamus, aliam inimus viam: Geometriam quidem adhibemus, ad explicandas, exponendasque praedictas illas proportiones, quae motibus insunt; sed effectus illos praedictis proportionibus affixos ad principia Physica reducimus; id est, cum supponamus quod sint, propter quid sint demonstramus" (Fabri 1646, *praefatio*, p. 5). My emphasis (in the last sentence); see also Chapter 1 above, Note 1.

words, "led local motion to where no mortal had led it before" – was asserting the correct "definition" of uniformly accelerated motion, $v \propto t$ (i.e. the direct proportionality between velocity and time) and deriving (and ultimately experimentally verifying) the "law of odd numbers", which states that the spaces traversed in equal consecutive times increase according to the series 1, 3, 5, 7 etc.[4] However, Galileo – within his mathematical examination of free fall – saw no point in entering "into the investigation of the cause of the acceleration of natural motion" and even criticized "various philosophers" who tried vainly to "reduce" it to various factors. "For the present", decides Galileo (from the mouth of Salviati), it suffices "to investigate and demonstrate some attributes [*passiones*] of a motion so accelerated (whatever be the cause of its acceleration) that the *momenta* of its speed go increasing, after its departure from rest, in that simple ratio with which the continuation of time increases" (Galilei 1989, p. 159).

Fabri, as we can see in the quoted passage, cannot accept Galileo's explicit abandonment of the search for the cause of natural acceleration; as we recall from Part I, true physics – according to Fabri – should indeed involve mathematics, but must also reduce natural effects to their causes. Fabri abides by Aristotle's demand, in his *Posterior Analytics*, to base scientific knowledge not on explanations *quod* (or *quia*), i.e. "of the fact," but on demonstrations *propter quid* – which can account for the observed facts by properly presenting their causes.[5] In retrospect, Galileo's decision should be regarded as an important step in the development of mechanics: by disregarding (temporarily, and ad hoc) any "causes" for free fall he was able to concentrate on a kinematical analysis and thus develop the law of fall and the parabolic trajectory of projectiles, his two most important contributions to the science of motion. However, contemporary physicists – and not only "conservatives" like the Jesuits, but also "innovators" like Descartes – could not accept Galileo's fresh attitude, being so much in conflict not only with the old notion of *scientia*, that demanded "causality" from scientific explanations, but also with the novel "mechanistic" approach which sought to reduce every kind of motion to an "impact model".

In her article "the use and abuse of mathematical entities: Galileo and the Jesuits revisited" Rivka Feldhay describes Galileo's failure, within his earlier writings, in his attempt to use the Archimedean hydrostatic model to account for natural acceleration. Following this dead end, explains Feldhay, Galileo – once a close ally of the Jesuits, who contributed significantly to the swift acceptance of his telescopic observations – pursued in his *Dialogo* (Galileo 1953, originally published in 1632) a new direction, and thus drifted away from his former friends: "Galileo's split from the 'mixed sciences' and his conscious attempt to create an alternative science of mechanics... brought about his growing estrangement from the discourse of Jesuit mathematicians" (Feldhay 1998, p. 103). Later Feldhay identifies Galileo's mathematical "continuous" approach to velocity – exemplified in his claim that a falling

[4]Galilei 1989, pp. 153–154, 167–169.
[5]See Mancosu 1996, pp. 10–12.

body, before arriving at a certain velocity, goes through all possible (infinite) smaller degrees of velocity – as well as his abovementioned decision to put aside the "cause" of natural motion, as the reasons for this "estrangement". Feldhay concludes that "excluding either a philosophical justification of the analysis of the continuum, as well as causal explanations of motion in term of weight or force" Galileo's theory of free fall "conflated different types of discourses, and transgressed the boundaries between mathematical and physical science" (ibid.).

Feldhay has pinpointed the elements in Galileo's theory which Fabri could not accept: Galileo's analysis of the continuum (i.e. his claim that any continuum is composed of infinite "mathematical" indivisibles), and the forsaking of the cause behind free fall. Fabri indeed adopted a discrete analysis, and of course (according to his general conception of motion, described in the first part) designated impetus as the cause responsible for falling bodies. However, as we shall see, Fabri eventually took pains to prove that his discrete approach converges to Galileo's continuous analysis if small enough "instants" are used; furthermore, he established impetus as the cause of fall, but took care to neutralize impetus (or weight, or any other physical magnitude) as a factor controlling the rate of fall, and fully accepted Galileo's contention that all bodies fall through the void at the same rate; and on top of this, Fabri adopted Galileo's "Archimedean" theory of fall, involving the abolition of Aristotle's "levity" as an inherent property of bodies. I think therefore it is fair to evaluate Fabri's theory of fall as a brave attempt to "reclaim" Galileo, and in a way remove the estrangement described by Feldhay. In other words, Fabri had to "correct" Galileo on these two important issues – in order to be able to finally assimilate to his physics (and teach his Jesuit students) Galileo's ideas, especially Galileo's law of falling bodies (in the void) and its corollaries (e.g., the dependence of the distance passed on the square of the time). But before explaining how Fabri, using his (initially) discrete approach, thus managed to "incorporate" the essentials of Galileo's theory, it is worth discussing Fabri's opinion concerning Aristotle's account of free fall.

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Chapter 7
Criticizing Aristotle

The second book of the *Tractatus physicus de motu locali*, i.e. *De motu naturali deorsum*, starts by establishing impetus as the cause of free fall, while criticizing the explanation of Aristotle, which had been warmly embraced by the scholastic tradition (e.g. Thomas Aquinas; see Section 5.1 above). In the first definition Fabri simply states that "natural local motion" is the downward motion "which is because of heaviness (*gravitas*)".[1]

7.1 Relinquishing Levity

Lukens remarks in a footnote that "it is of interest that he ignores the Aristotelian concept of levity".[2] In fact, this is a matter so much "of interest" that it is worth describing briefly – before continuing to the second definition – Fabri's full-blown approach towards Aristotle's conception of natural motion in general and levity in particular, which appears in his later work *Physica* (1669–1671). There, in proposition 28 of *De gravi et levi* (the fourth book of *Tractatus primus* of his *Physica*), Fabri declares that "every body is heavy by absolute heaviness", and that not only does "absolute levity not exist", but also that – regarding motion of heavy things – "Aristotle was not as accurate as one would perhaps wish, in what was indeed proved by Galileo as complete falsehood".[3] Fabri maintains that this opinion – denying absolute levity – could be found also in Aristotle himself, who claims that "heavy and light are the same as dense and rare" and that air is both heavy and light.[4]

[1] "Motus localis naturalis est, qui est a gravitate deorsum" (Fabri 1646, lib. 2, def. 1, p. 74).

[2] Lukens 1979, p. 143, n. 3.

[3] "Propositio XXVIII: Omne corpus est grave gravitate absoluta... Immo ostendam infra, nullam dari levitatem absolutam; & vero, ut dicam quod res est, in iis quae pertinent ad gravium, non tam accuratus fuit Aristoteles, quam aliquis forte desideraret, in quo sane multae falsitatis a Galilaeo convictus est" (Fabri 1669–1671, tr. 1, lib. 4, prop. 28, p. 254).

[4] "Venio ad Atistotelem, qui multis in locis nobis aperte favet, scil. lib. 4, ph. c. 9, lib. 8, c. 7, lib. 3, *de caelo* c. 1. ubi dicit grave et leve idem esse quod densum & rarum; lib. 3. *de caelo*, cap. 2. asserit aera aptum esse gravem & levem" (Fabri 1669–1671, tr. 1, lib. 4, prop. 62, p. 267).

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However, despite his attempt to avoid portraying himself as a staunch opponent of the Philosopher, Fabri does not hesitate to add that "indeed I admit that Aristotle has written some things about heaviness that contradict manifest experiences and arguments. For instance, that of two unequal bodies, of the same material and shape, the bigger descends faster; that of two equal bodies, but of a different material, the heavier descends faster according to the proportion in which it is heavier; that the same heavy object descends through diverse media according to the proportion in which one medium is denser than the other." These claims, which constitute Aristotle's conception of falling bodies, are flatly rejected by Fabri, and he immediately emphasizes that "there is nothing wrong in deviating from Aristotle if either a manifest experience or an evident argument compels [us to do so], and indeed he says many things to which are opposed either divine faith... or manifest argument and experience".[5]

Fabri, in any case, does not hide the real tradition from which he drew the abolition of absolute levity. He mentions, within proposition 28 of *De gravi et levi*, the "great Archimedes", who was the first to "ponder over gravity" – and also recent figures like Galileo, Torricelli, and the Jesuit Niccolò Cabeo – as supporters of this view,[6] which became rather common among Jesuit scholars. For example, the Jesuit mathematician Paulo Casati claimed in his *Mechanicorum libri* (1684) that an ascent of a stone differed from its descent only in regard to "which ubication the stone obtains at last, after the other ubications towards the end of the movement", and concluded that "in order to change this order it seems that a dissimilitude of the moving force is not necessary, because actually nothing dissimilar happens"; thus Casati in effect undermined the whole debate on levity, ultimately claiming it to be terminological rather than substantial.[7] In fact, rejecting "positive levity" became so popular, even in Jesuit circles, that the Jesuit Pierre Le Cazre tried (in vain) to

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Aristotle's remark, identifying "heavy" with "dense" and "light" with "rare", is indeed hard to understand within his general scheme, according to which the terms "heavy" and "light" imply natural movements towards or away from the center (*On the Heavens* [Aristotle 1953], 1, 3, 269b23–24).

[5] "Equidem fateor Aristotelem nonnulla de gravitate scripsisse, quae manifestis repugnant experimentis & rationibus; v.g. ex duobus corporibus inaequalibus, eiusdem materiae, & figurae, maius velocius descendere; ex duobus aequalibus, sed diversa materiae, gravius in ea proportione velocius descendere, in qua est gravius; idem grave per diversa media, in ea proportione descendere, in qua unum medium alio densius est. Sed haec falsa esse omnino, iam alibi demontravimus. Porro discedere ab Aristotele, si quando vel manifestum experimentum, vel evidens ratio cogit nullum vitium est, & vero multa dicit, quibus vel divina fides adversatur... vel manifesta ratio, & experientia" (Fabri 1669–1671, tr. 1, lib. 4, prop. 62, pp. 267–268).

[6] "Huic sententiae authores non desunt. Magnus Archimedes ad instar omnium esse posset; nempe ille primus gravitatis principia ponderavit; huic accedit Galileus, in libro quem de innantibus inscripsit, cui adde successorem Torricellum..." (Fabri 1669–1671, tr. 1, lib. 4, prop. 62, p. 267).

[7] "Quandoquidem motus, qui in eadem linea perficitur, similes plane includit ubicationes successive acquisitas, sive ascensus sit, sive descensus, ordine tantum in earum adeptione, commutato. Quare cum ascensus a descensu hoc uno differat, quod quam ubicationem lapis demum obtineret post alias prope finem motus... ad ordinem hunc permutandum non videtur necessaria virtutis motricis dissimilitudo; nihil quippe producitur dissimile..." (Casati 1684, lib. 1, cap. 2, pp. 11–12); quoted

prevent the Jesuit authorities from including it among the condemned opinions of the 1651 *Ordinatio pro studiis superioribus*.[8]

In the latter part of *De motu naturali deorsum* (starting with theorem 71), where we can find a detailed analysis of motion through material media, Fabri discloses the ultimate origin of his basic conception of falling bodies. Theorem 86 claims that a medium detracts from the heaviness of body inserted in it an amount which is equal to the weight of the medium itself (supposing, of course, the same volume). For example, "if the heaviness of the medium is half" – i.e. if (in modern terms) the specific gravity of the medium is half of the body's – then the medium "detracts half of the heaviness; if [it is] tenth, [then the medium detracts] tenth, and so on." The source of theorem 86 is of course none other than Archimedes' proposition 7 from *On floating Bodies*,[9] and Fabri duly and immediately acknowledges the "great Archimedes", who – along with "everyone else, especially the more recent Galileo" – supported this theorem.[10]

Fabri indeed followed in Galileo's footsteps in conveying a dynamic meaning to Archimedes' hydrostatic propositions, thus deducing from a theory that analyzes states of *equilibrium* – relying on differences in specific gravities – conclusions concerning *motion* of bodies through media.[11] Galileo, in his early *De motu* (ca. 1590), declared that "since heavy bodies have, by reason of their heaviness, the property of remaining at rest under lighter bodies – inasmuch as they are heavy, they have been placed by nature under the lighter – they will also have the property, imposed by nature, that, when they are situated above lighter bodies, they will move down below these lighter bodies, lest the lighter remain at rest under the heavier, contrary to the arrangement of nature".[12] Fabri adopts Galileo's "dynamization" of Archimedes' hydrostatics, which would have probably shocked Archimedes himself, and certainly aggravated the followers of his mathematically rigorous and purely static

in Feldhay and Even Ezra, "Gravity and Levity in the 17th Century: A Jesuit Perspective" (forthcoming in the Max Planck Institute for History of Science Preprint Series). Casati further concludes that owing to the fact that there is no substantial difference between levity and gravity – both are a result of an interaction between the stone and its environment – we might as well reject gravity instead of levity; it should be added that although Casati's *Mechanicorum libri* was published in 1684, it was actually based on a course given at the *Collegio Romano* in the early 1650s (ibid.).

[8] See Hellyer 2003, pp. 30–32.

[9] "A solid heavier than a fluid will, if placed in it, descend to the bottom of the fluid, and the solid will, when weighed in the fluid, be lighter than its true weight by the weight of the fluid displaced"; Archimedes 1953, p. 258. The volume of the fluid displaced is equal, of course, to the volume of the immersed body.

[10] "Medium grave detrahit eam partem gravitationis corporis gravioris, quae est aequalis suae gravitationi. v. g. si medii gravitas est subdupla, detrahit subduplum gravitationis; si subdecupla, subdecuplum, atque ita deinceps; hoc iam olim supposuit magnus Archim. supponunt etiam reliqui omnes, praesertim recentior Galileus" (Fabri 1646, lib. 2, th. 86, p. 119).

[11] See also Moody 1951, pp. 170–171.

[12] Galilei 1960, p. 16. Galileo, as we can easily discern from the First Day of the *Two New Sciences*, never abandoned this general view. The crucial difference between his *De motu* and *Two New Sciences* concerns motion in a vacuum; see Damerow et al. 2004, pp. 269–270.

approach, like Simon Stevin.[13] The Jesuit declares that "a heavy body descends under a lighter medium", a fact which arises "from the very nature of heaviness (*gravitas*), by which a heavy body tends downwards", and echoes Galileo's statement in *De motu* by asking: "who will deny that a heavy body descends under a lighter one, in order to occupy a certain place that it lacked before, which is nevertheless connatural to it in this order of things?"[14] The remainder of *De motu naturali deorsum* is dedicated to analyzing natural motion through media according to this Galilean "order of things" (which acknowledges only one natural "absolute" inclination of bodies: downwards), in terms of differences of specific gravity – the means Archimedes provided for investigating states of equilibrium. This whole part will indeed show that Fabri's views concerning free fall (not only through material media, but also in the void) are much closer to Galileo's than most (if not all) historians have acknowledged and that the issues in which Fabri does object to Galileo are not necessarily the bone of contention between "conservatives" and "innovators".[15]

7.2 The Internal Cause of Natural Motion

But let us return now to the beginning of *De motu naturali deorsum*, which starts by analyzing free fall in the void, not in material media. The second definition merely redefines uniform motion ("that in which, in any equal times whatever, equal spaces are traversed by the same mobile"), and the third one defines naturally accelerated motion: "Naturally accelerated motion is that in which, in the second equal time, more space is acquired than in the first, and more in the third than in the second, and more in the fourth than in the third, and so on. There is no force added from outside, at least perceptibly".[16]

The first hypothesis[17] claims that "a heavy body falls downwards, and falling from a higher altitude it inflicts a stronger blow (*maius ictus*) than falling from

[13] See Gaukroger and Schuster 2002, pp. 542–550.

[14] "Sub medium levius corpus grave descendit... ratio porro petitur ex ipsa gravitatis natura, qua corpus grave tendit deorsum... quis enim neget corpus grave ideo descendere sub levius, ut occupet aliquem locum quo prius carebat, qui tamen illi connaturalis est in hoc rerum ordine?" (Fabri 1646, lib. 2, th. 80, p. 117).

[15] It should be mentioned, however, that Fabri does not accept Galileo's analysis of the resistance which a body encounters while passing through a medium. For example, Fabri rejects Galileo's (valid) assertion that a body which falls through a material medium eventually ceases to accelerate and continues with a terminal velocity (see Lukens 1979, pp. 207–210).

[16] "Definitio 2: Motus aequabilis est, quo aequalibus quibuscunque temporibus aequalia percurruntur spatia ab eodem mobili; Definitio 3: Motus naturaliter acceleratus est, quo secundo tempore aequali primo maius spatium acquiritur, & tertio, quam secundo, & quarto quam tertio, atque ita deinceps; nulla scilicet addita vi ab extrinseco saltem sensibiliter" (Fabri 1646, lib. 2, defs. 2, 3, p. 74). Lukens's translation (Lukens 1979, p. 143).

[17] For Fabri's conception of "hypothesis" see Chapter 2 above.

a lower one".[18] The second hypothesis asserts that "larger and smaller arcs of the same pendulum are traversed almost in equal times" (*Arcus maior & minor eiusdem funependuli aequalibus fere temporibus*, *percurruntur*), and the third one emphasizes that acceleration exists not only within falling bodies but also in motion downwards along inclined planes.[19] Later Fabri claims that since – relying on these hypotheses – natural motion is swifter at the end (for as the duration of fall is longer, so the resulting "blow" is stronger, and of course also the velocity), its immediate cause could not be heaviness, which is constant.[20] Hence the cause of free fall – i.e. natural acceleration – must be an entity that increases in time: impetus. Since Fabri's intention is to relate free fall to an *internal* cause (impetus), while the old Peripatetic tradition had ascribed it to an *external* source – i.e. lying outside the falling object itself – he must address this problem before showing that impetus is the real cause of accelerated natural motion. He does this in the first theorem of *De motu naturali deorsum*.

Theorem 1 includes objections not only to Aristotle's opinion, but also to other free fall explanations prevalent at the time, which are worth mentioning. The theorem simply states that "natural local motion exists, and it is from within" (*Datur motus localis naturalis*, *isque ab intrinseco*). Fabri now devotes considerable attention to refuting possible explanations of free fall involving external reasons. He starts with the "first cause", i.e. God, and explains that "that effect ought to be attributed to a first cause, which can have no applied second cause. But this effect [of acceleration] *can* have a second cause, which I will assign below".[21] Thus God, the "last resort" of explaining natural phenomena, is not needed here.

Now Fabri rejects one of the explanations which Galileo – declining to engage in causal inquiry – labeled (in his *Two New Sciences*) as "fantasies" whose examination would bring about "little gain" (Galilei 1989, p. 159): the assertion that the air "extrudes" the body downwards. Fabri simply claims that the surrounding medium resists – not assists – the motion of a body moving in it. The third "external" explanation rejected by Fabri is a magnetic force of attraction.[22]

The fourth opinion Fabri criticizes claims that natural motion downwards is caused by "a pushing force of some kind, which some assign to the heavens". Fabri explains that such a reasoning will not do: for if the pushing force comes only from one part of the sky, then the necessary result would be that under most regions of the sky a body would be pushed in other directions, not downwards; and if the pushing force comes from everywhere, then the body would be pushed from every direction

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[18]"Corpus grave cadit deorsum, & cadens ex maiori altitudine maiorem ictum infligit quam si caderet ex minore" (Fabri 1646, lib. 2, hyp. 1, p. 74).

[19]Fabri 1646, lib. 2, hyps. 2, 3, p. 75.

[20]Fabri 1646, lib. 2, th. 4, p. 80.

[21]Fabri 1646, lib. 2, th. 1, p. 76. Lukens's translation and emphasis (Lukens 1979, p. 147).

[22]Fabri 1646, lib. 2, th. 1, p. 77. For a full discussion concerning the issue of magnetic force see Lukens 1979, pp. 148–150.

at once, and thus would not move at all.[23] As Lukens remarks, this "refuted doctrine resembles Descartes' explanation of *gravitas* in his *Principia philosophia IV, 20–27*", though "Fabri does not name any philosopher in this section".[24] Descartes, in Part IV of his work, entitled "The Earth", indeed explains (in article 23) "how all the parts of the earth are driven downwards by the celestial matter, and so become heavy".[25]

Descartes for his part paid heed to Fabri's indirect criticism, and his surprisingly irrelevant response probably indicates that he was rather upset by the Jesuit's indirect attack. Here is Descartes' response, from a letter he sent to Mersenne on 26 April 1647, after reading (not very attentively, as will soon be evident) Fabri's *Tractatus physicus de motu locali*:

> [Fabri] says that bodies called heavy cannot be attracted by the earth, or pushed towards it by some subtle matter (which is against me), from which he concludes that they themselves must possess a quality that makes them descend… He says that the subtle matter is light (*il dit que cete matiere subtile est la lumière*), according to the opinion of those who have invented it (that is to say myself), and that, in consequence, bodies in dark cellars should not have as much gravity as if they were exposed to the sun; but our experiments show the contrary. From which it can be seen that he has really read what I have written, but that he has understood it very badly; for I have never said that subtle matter was light, nor that it was gravity (*car ie n'ay iamais dit que la matiere subtile fust la lumière*, *ny aussy qu'elle fust la pesanteur*), but that it has several different actions, one of which excites in us the sensation of light (*le sentiment de la lumière*), and the other makes heavy bodies descend towards the earth. And these two actions no wise prevent each other, as I have sufficiently proved.[26]

Why does Descartes claim here that Fabri attributed to him the contention that "subtle matter is light (*lumière*)?" In any case, what do light (*lumière*) and "dark cellars" have to do with Fabri's argument? The mystery unfolds when we read the fifth opinion Fabri criticizes, according to which "bodies are extruded downwards by light itself". He simply objects that "in the night bodies are carried downwards by the same motion as if it were daylight", and in "the darkest chamber" as if it were "under the open sky"; furthermore, bodies underground, in places totally devoid of light, also fall at the same rate.[27] Descartes, who accuses Fabri of understanding

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[23] "Quarto, motus naturalis non est a virtute quadam pellente, quam caelo quidam affingunt; nam vel ab omni parte caeli deorsum truderetur, vel ab una; si ab una; igitur in omni caeli plaga corpus non fertur deorsum; si ab omni, ergo cum pellatur corpus per plures lineas etiam oppositas moveri non potest" (Fabri 1646, lib. 2, th. 1, p. 78). Assuming that the pushing force is simply directed radially, towards the center of the earth, would be begging the question.

[24] Lukens 1979, p. 150, n. 23.

[25] *Principles of Philosophy*, part IV, art. 23, in Descartes 1984–1985, vol. I, p. 269.

[26] Tannery et al. 1945–1988, vol. XV, p. 210; translation copied (with some changes) from Dugas 1958, p. 190, n. 3.

[27] "Quinto, aliqui recentiores existimant corpora deorsum trudi ab ipsa luce… sed neque hoc probari potest. Primo quia de nocte corpora aequali motu deorsum feruntur; perinde atque de die, nec minus in obscurissimo conclavi, quam sub dio, vel aperto caelo; Secundo, in subterraneis locis etiam gravia aeque velociter descendunt; licet eo lumen non penetret" (Fabri 1646, lib.2, th. 1, p. 78).

his theory "very badly" seems to have confused Fabri's fourth objection (against a pushing force from heaven) with the fifth one (against light), while Fabri does not at all associate Descartes' subtle matter with light and clearly separates between these two dismissed theories. Furthermore, Descartes fails to address Fabri's cogent argument against the fourth opinion, i.e. against Descartes' explanation of gravity.

But Fabri's most important objection – in the current context of criticizing the Aristotelian tradition – is the sixth one, directed against the "stricter Peripatetics", who claim "that heavy things are moved downwards by the *generans* which was expressly conveyed by Aristotle in Chapter 4 of the eighth book of his *Physics*, according to his most universal principle, *quidquid movetur*, *ab alio movetur*".[28]

With this significant remark, Fabri alludes to a problematic issue in Aristotle's theory of motion, which exemplifies Aristotle's difficulties concerning motion whose "moving agent" is not apparent – for instance, the motion downwards of the heavy elements, earth and water. The Stagirite does indeed admit, in *Physics*, 4, 8, that "it is in these cases that difficulty would be experienced in deciding whence the motion is derived, e.g. in the case of light and heavy things".[29] Aristotle's difficulty is obvious: we have seen (in part one) that according to Aristotle's "definition of motion", appearing in the second book of his *Physics*, "nature" is a cause of being moved "*in* that to which it belongs primarily".[30] Aristotle might have been expected to claim that the source of natural motion lies within heavy objects, rather than outside. But he does not; he claims that "it is impossible to say that their motion is derived from themselves: this is a characteristic of life and peculiar to living things".[31] And yet, analyzing natural motion from the point of view of "actualizing potentialities", Aristotle explains that the reason for it is that light and heavy bodies "have a natural tendency respectively towards a certain position: and this constitutes the essence of lightness and heaviness", i.e. the "potentialities" whose process of "actualization" results in upward or downward motion.[32] Aristotle does not regard these forms as "movers", but as "principles", or "proper activities"; he adds that "in

[28] "Sexto, sunt denique multi, iique ex severioribus Peripateticis, qui existimant gravia moveri deorsum a generante, quod expressis verbis traditum est ab Aristotele l. 8. *phys*. cap. 4. iuxta principium illud universalissimum: Quidquid movetur, ab alio movetur; sed profecto ii ipsi, qui motum gravium generanti tribuunt, tanquam principi causae, non negant inesse gravibus gravitatem, quae sit principium activum minus principale motus; ad quem etiam, ut ipsi existimant, forma substantialis concurrit; In hoc quippe conveniunt omnes tum sectarum Principes, tum recentiores: quidquid sit etiam ex iis ipsis datur motus naturalis, qui est a virtute proxima intrinseca; hoc ipsum etiam sensit Aristoteles lib.4. *de caelo* cap. 3. t. 25. ubi ait gravibus & levibus inesse principium activum suorum motuum; immo si totum cap. 4. l.8. *phys*. attente legatur, ubi dicit moveri a generante, haud dubie intelligetur nihil aliud intendisse Aristotelem quam gravia a generante, instanti, quo generantur, accipere actum primum huius motus; id est virtutem, a qua possint reduci ad actum secundum, id est ad ipsum motum, de cuius rei veritate iam mihi non est laborandum" (Fabri 1646, lib. 2, th. 1, p. 79).

[29] *Physics* [Aristotle 1930], 8, 4, 255a1.

[30] *Physics* [Aristotle 1930], 2, 1, 192b22; my emphasis; see Chapter 1 above.

[31] *Physics* [Aristotle 1930], 8, 4, 255a5.

[32] *Physics* [Aristotle 1930], 8, 4, 255b15.

all these cases the thing does not move itself, but it contains within itself the source of motion – not of moving something or of causing motion, but of suffering it".[33] As we have seen in Section 5.1, Thomas Aquinas defined them as "formal principles" and emphasized that they were not *motores coniuncti*, while the Coimbra Jesuits stated clearly that they should not be seen as efficient causes of (upwards or downwards) motion. What, then, is the mover in the case of natural motion, according to Aristotle? At the end of chapter four he conveys at last his opinion: light things and heavy things "are moved either by that which brought the thing into existence as such and made it light and heavy; or by that which released what was hindering and preventing".[34] Aristotle also remarks that an agent who removes an obstacle to natural motion, e.g. "pulls away a pillar from under a roof", is only the accidental cause of motion.[35] We are left then with the conclusion that the real "mover" in the case of natural motion – according to Aristotle – is whatever produced the moving object in the first place, i.e. its *generans*. Thomas, as we have seen in Section 5.1, adopted this conclusion.

Fabri, who wishes to establish an inner cause for free fall – to be eventually identified as impetus – must contend with Aristotle's "external" explanation. Aristotle attributed natural motion (whether upwards or downwards) to the *generans*, according to the principle concerning inanimate objects, "everything which moves is moved by something else" (according to Aristotle living things can move themselves, and thus obey the more general dictum, "everything that is in motion is moved by something").[36] Fabri chooses to achieve his goal not by a confrontation with Aristotle, but by reinterpreting him, along the lines of Thomas Aquinas's view. Fabri therefore uses the abovementioned "potentialities", i.e. "principles" or "proper activities" which according to Aristotle were the internal factors (indirectly) responsible for the motion downwards. These entities – Thomas's "active principles" – cannot of course be regarded by this Peripatetic tradition as real "movers", because that would violate Aristotle's dicta. Fabri, therefore, immediately after admitting that Aristotle depicted the *generans* as a mover, asserts (see Note 28 above) that "surely, those who attribute the motion of heavy things to the *generans* as a principle cause, do not deny that inside heavy things there exists heaviness (*gravitas*), which would be a less principal active principle (*principium activum minus principale*) of motion, to which also – as they think – a substantial form is connected".

Fabri does not claim that he himself believes in "substantial forms" which inhere in falling inanimate objects and cause them to move; he indeed elsewhere "admits but one 'substantial form', that of man, to be precise, his rational soul".[37] Fabri now draws the conclusion that is important to him: "even according to themselves" – he asserts (Note 28 above), referring again to these "stricter Peripatetics" – "natural

[33] *Physics* [Aristotle 1930], 8, 4, 255a23–30 and b30.

[34] *Physics* [Aristotle 1930], 8, 4, 256a1.

[35] *Physics* [Aristotle 1930], 8, 4, 255b25.

[36] *Physics* [Aristotle 1930], 7, 1, 241b24.

[37] Blum 1999, pp. 243–244; see also Section 19.4 below.

motion exists, which arises from an immediate intrinsic power." He adds that "even Aristotle sensed this" in his *On the Heavens*, "where he says that in heavy and light things there exists an active principle of their own motions".[38] Fabri concludes his interpretation of Aristotle's theory by claiming that "if the entire fourth chapter of the eighth book of the *Physics* – where he says that this motion arises from the *generans* – is read attentively, no doubt it will be understood that Aristotle meant that heavy bodies, in the moment of their generation, receive from their *generans* the first act (*actus primus*) of this motion, i.e. a power, by which they could be reduced to the second act (*actus secundus*), i.e. motion itself" (Note 28 above).[39]

Fabri associates then Aristotle's inner principle of motion of heavy things (originally, the potentiality whose process of actualization results in free fall) with a body's heaviness (*gravitas*). Soon we shall see how he connects heaviness to (natural innate) impetus, but before that it is worth consulting Fabri's opinion on this matter in his *Metaphysica*. Interestingly, in contrast to the "conciliatory" approach in the *Tractatus* described above, in the *Metaphysica* we can discern a much more aggressive tone towards Aristotle. In the seventh book, *De causis et actione*, Fabri discusses (in proposition 15) Aristotle's principle *quidquid movetur*, *ab alio movetur*, and explains that a controversy can arise between the "authority of Aristotle" and "clear experiences", which show that sometimes something is moved by itself; "for who would deny that a stone which falls downwards is moved by itself?" Here Fabri does not use Aristotle's "potentialities" in order to reconcile the Stagirite's "external" explanation of natural acceleration with his own "internal" one; rather, he continues to criticize Aristotle for failing to handle properly this whole issue:

> Regarding heavy things, which move downwards, Aristotle examined only innate impetus,[40] by which they first move or gravitate, and which exists by the *generans*;[41] for he did not examine accelerated motion, which perhaps he believed was caused by the air, and accordingly he did not labor much on it, in order to prove his aforementioned axiom.[42]

According to Fabri, Aristotle supplied an explanation why natural motion *begins* – namely, the "innate impetus" (heaviness), that is provided to the falling body by its *generans* and confers on it the "first act" of motion – but failed to

[38] *On the Heavens* [Aristotle 1953], 1, 2, 268b28.

[39] The notion of a "second actuality" as a "higher", or "more actual", manifestation of a "first actuality" (or a "habit") is prevalent in mainstream scholastics, especially in the writings of Thomas Aquinas; Lang 2002, p. 578.

[40] Namely, gravity (or heaviness), in Fabri's terminology.

[41] The creator of a body, which forms within it this "innate impetus".

[42] (The "aforementioned axiom" is *quidquid movetur ab alio movetur*.) "Utrum vero, quidquid movetur, ab alio moveatur, vel immutetur, controversia esse potest, cum pro parte affirmante faciat authoritas Aristotelis; pro negante vero manifestae experientiae demonstrent, idem a se ipso aliquando moveri; quis enim neget lapidem, qui deorsum ruit, moveri a se?... Quod vero spectat ad gravia, quae deorsum eunt, consideravit tantum Aristoteles impetum innatum, quo primum moventur, vel gravitant, qui est a generante; nec enim consideravit motum acceleratum, quem forte ab aere esse putavit, ac proinde non multum de illo laboravit, ut praedictum illud suum axioma probaret" (Fabri 1648, lib. 7, prop. 15, pp. 273–274).

"examine accelerated motion" itself. Thus it is easily understood why Fabri – unable to find within the Peripatetic tradition an explanation (or even a description) of natural acceleration – realized that in order to properly account for natural acceleration, he could rely on one existing explanation only: that of Galileo. Fabri adds that Aristotle "perhaps" believed that the reason for natural acceleration was air, thus strangely ignoring the fact that Aristotle explicitly stated that air was indeed responsible for this effect.[43] Interestingly, in the *Tractatus* Fabri – according to his more conciliatory approach – categorically denies that Aristotle ever held such a "ridiculous" attitude regarding natural acceleration.[44] It is no wonder that Fabri, who regards the air as a factor inhibiting motion rather than accelerating it, deems this opinion "ridiculous". It is interesting however that in the *Metaphysica* Fabri does attribute it to Aristotle, and it is very strange that he fails to state that Aristotle has indeed claimed this explicitly. In any case, it is clear that Fabri does not find either Aristotle's explanation of natural motion or the statement *quidquid movetur, ab alio movetur* very satisfactory. Soon afterwards Fabri indeed claims:

> Therefore, having eliminated all these excuses, I would claim that it is better to somewhat correct Aristotle's opinion on this matter, which most of the illustrious philosophers failed to do; therefore. . . it is certain that something can be locally moved by itself; as is apparent in heavy things; and no argument can be brought, from which the contrary would be proved.[45]

Fabri concludes that the principle *quidquid movetur*, *ab alio movetur* is correct concerning rarefaction, alteration and generation, but not with regard to local motion:

> Therefore, I only briefly indicate that from the four motions (or mutations) of bodies, which Aristotle enumerates, which are translation [*latio*], rarefaction, alteration and generation, there is only one, namely the first, about which the aforementioned dictum "whatever is moved, is moved by another" is not valid.[46]

Thus Fabri transformed Aristotle's dictum (concerning inanimate objects) *omne quod movetur ab alio movetur* to the statement *omne quod movetur ab aliquo movetur*, as far as local motion is concerned. This transformation, of course, is not an original contribution of Fabri's theory; it is already implied in the fourteenth century theory of impetus. Annaliese Maier explains that

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[43] See *On the Heavens* [Aristotle 1953], 3, 2, 301b17–30.

[44] "Tertio reiicies, qui volunt motum accelerari ex aeris a tergo impellentis appulsu, quod ridiculum est: licet enim Aristoteles videatur illud sensisse de projectis, quod examinabimus suo loco; nunquam tamen hoc dixit de motu naturali" (Fabri 1646, lib. 2, th. 61, cor. 3, p. 97).

[45] "Igitur omissis omnibus illis excusationibus; dicam potius parum curandum in hoc negotio, de mente Aristotelis, quem plerique ex illustrissimis Philosophis, in hoc deserunt; itaque primo certum est, aliquid a se ipso moveri posse localiter; ut videre est, in gravibus; nec ullam rationem afferri posse, qua contrarium probetur" (Fabri 1648, lib. 7, prop. 15, p. 274).

[46] "Quare breviter tantum indico ex quatuor motibus, vel mutationibus corporum, quas recenset Aristoteles, quae sunt latio, rarefactio, alteratio, generatio, unicam tantum esse, scilicet primam, in qua pronunciatum illud non valeat, *quidquid movetur*, *ab alio movetur*" (Fabri 1648, lib. 7, prop. 15, p. 274).

> the concept of an inherent force that moves the object it belongs to [a concept underlying Buridan's explanation of free fall; M. E.] derives from the axiom *omne quod movetur*, *ab aliquo movetur*: every motion needs a mover, not only to initiate it, but also to maintain it. In those cases in which no external mover is present, an inherent force is a sufficient substitute; this is the improvement on Aristotle's conception that scholastic thinkers introduced. (Maier 1982, p. 52)

Except for the fact that Fabri – as we saw in the first part – defined "impetus" purely as a "quality", and not as a "force", Maier's adequate summation is as relevant to Fabri as to the fourteenth century protagonists of impetus.

At the end of theorem one of *De motu naturali deorsum* Fabri concludes that therefore "heavy bodies are not moved by a first cause... not by the air, not by a magnetic force... not by the heavens pushing them, nor by their *generans* immediately". Having (allegedly) brushed aside every possible extrinsic cause for natural motion, Fabri reaches the unavoidable (and desired) result: this cause must be internal.[47]

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[47] "Igitur non movetur corpus grave a causa prima... nec ab aere, nec a virtute magnetica... nec a caelo pellente, nec a vi sympathica, nec a generante proxime & immediate... nec ab ullo alio extrinseco, ut constat inductione; igitur ab aliqua vi intrinseca, quidquid sit, de qua alibi" (Fabri 1646, lib. 2, th. 1, p. 79).

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Chapter 8
The Law of Natural Numbers

In the first theorem of the second book of the *Tractatus physicus de motu locali*, "On Natural Motion Downwards", Fabri has established his opinion that the cause responsible for free fall is not external, by ruling out not only the old Peripatetic tradition but also the contemporary Cartesian approach, and to some degree – by rejecting a (magnetic) force of attraction as a possible cause for free fall – also Newton's future explanation. In the second theorem Fabri starts his "positive" account: he begins by identifying the cause of motion (thus rejecting Galileo's decision to abstain from a causal analysis), and then he gradually develops his "natural numbers" law – that in each successive (equal) amount of time a falling body passes a distance which is one unit bigger than its immediate predecessor, i.e. according to the simple series 1, 2, 3, 4, 5 etc. This chapter will briefly reconstruct Fabri's deduction of his law of falling bodies, while the next one will emphasize – *pace* Lukens and Drake – the crucial difference between his view and Buridan's outlook.

Theorem 2 of *De motu naturali deorsum* applies theorem 1 of the first book (*De impetu*), which declares that motion is "something really distinct from the mobile", to natural motion, and uses the same argumentation ("moving" and "not moving" are contradictory predicates).[1] If natural motion were not distinct from the falling body, a distinct reason would not be needed at all, and causal analysis would be superfluous. The next two theorems examine two possible "internal" sources for natural motion and reject them. Theorem 3 claims that it does not arise "immediately" from the "entity of the mobile", because while the entity of the mobile is constant, the effect of free fall depends on the height: the higher the altitude of fall, the greater the effect (the hitting force of the falling object) and hence the faster the natural motion. In other words, a constant factor (the mobile's entity) cannot be considered as the cause of a varying effect (the speed of a falling body). Theorem 4 says that natural motion does not arise "immediately" from "heaviness itself (*ipsa*

[1] Fabri 1646, lib. 2, th. 2, p. 79.

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gravitas)", for the same reason – heaviness stays the same, while the effect of free fall (and therefore necessarily its cause) varies.[2]

Theorem 5 finally discloses the cause for free fall: "Hence natural motion arises from impetus". Fabri explains that as an entity which must be a result of something else (only God is not the result of anything else), natural motion must be a result of a cause,[3] and having rejected every possible external explanation, as well as internal "entity" and *gravitas* – only impetus is left, "because there is nothing else intrinsic by which motion could arise according to the third definition of the first book".[4] Fabri's claim that he has in effect refuted every (external and internal) remaining reason for natural motion – other than impetus – is of course not very convincing. It is this type of argumentation which urged Leibniz to demand from his Jesuit correspondent, 38 years his senior, "I would like, however, that you were little more severe in demonstrating than you have been".[5]

But now – ignoring Fabri's problematic reasoning, and assuming that he has successfully proven that natural motion is an immediate result of impetus – a new question arises: how is this impetus created? The following theorems try to settle this issue. Impetus has to be caused by an "intrinsic cause", explains Fabri, otherwise natural motion itself would be extrinsic – an assumption already refuted in theorem 1.[6] Fabri claims that the only possible cause for this impetus is "the substance of the heavy body itself (*substantia corporis gravis*)",[7] and then turns to clarifying the mechanism of its gradual creation:

> The impetus produced in the first instant lasts (*durat*) in the next following instant. This is proved since it always has its formal effect; either of being heavy if impeded, or of motion in a free medium. Therefore it is not in vain, and therefore it is not destroyed. . . [for] nothing exacts [its] destruction.[8]

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[2]"Theorema 3: Motus naturalis non est immediate ab entitate mobilis, ita ut nihil sit aliud unde sit hic motus: Probatur; lapis cadens ex maiore altitudine maiorem ictum infligit per hypoth. 1. maior est effectus, igitur maior causa, id est motus; igitur causa motus per Ax.2. sed est eadem entitas mobilis, ut patet; igitur non est causa immediata motus. . . Theorema 4: Motus naturalis non est immediate ab ipsa gravitate. Probatur, sint enim eaedem hypoth. 1.2.3. igitur maior ictus in fine motus, & velocior motus debent habere causam; sed haec gravitas non est, quae semper eadem est, ut patet" (Fabri 1646, lib. 2, ths. 3–4, p. 80).

[3]Fabri refers the reader to axiom 8 in the first book: "Quidquid primo est, & ante non erat, habet causam distinctam" (Fabri 1646, lib. 1, ax. 8, p. 8).

[4]"Hinc motus naturalis est ab impetu. Probatur; est ab aliqua causa per Ax.8. lib.1; ab aliqua intrinseca per Th. 1; non a substantia corporis gravis per Th. 3; non a gravitate per Th. 4; igitur ab impetu, quia nihil aliud esse potest intrinsecum, a quo sit motus per definitionem 3. lib. 1." (Fabri 1646, lib. 2, th. 5, p. 80).

[5]See Leibniz 2006, p. 237.

[6]Fabri 1646, lib. 2, ths. 6–7, p. 81.

[7]Fabri 1646, lib. 2, th. 8, p. 81.

[8]"Impetus productus primo instanti durat proxime sequenti. Probatur primo; quia semper habet suum effectum formalem; vel gravitationis, si impeditur; vel motus in medio libero; igitur non est frustra; igitur non destruitur per Th. 162, lib. 1. nihil enim exigit destructionem" (Fabri 1646, lib. 2, th. 9, p. 81).

We already know that impetus is a non-modal accident, i.e. an accident which is separable (though only by a miracle) from its subject, and which has – in addition to inhering in a subject – a "secondary formal effect", namely motion (Section 4.2 above). Fabri here expands this explanation, and adds that if the heavy body is impeded, and thus does not fall to the ground, the impetus created "in the first instant" is still "not in vain" (and thus it is not destroyed): it causes pressure downwards, on whatever impedes its downward motion. Now Fabri explains that "this innate impetus, which endures in the second instant, is conserved by a certain cause",[9] relying on axiom 14 from the first book, that "whatever is destroyed does not exist by itself". This cause, claims Fabri, cannot be the "initial productive cause" (*causa primo productiva*) – i.e. "the substance of the heavy body itself" (according to theorem 8, as shown above) – "otherwise the impetus could not be intensified (*intendi*) by the same cause... for conservation is nothing else than repetitive production".[10] Fabri means that the original cause for the production of this "innate impetus" (i.e. the substance of the body itself) cannot be considered as the cause responsible for the continuing duration of this impetus, because if it were, it could not be regarded as the cause responsible for the gradual increase of the falling body's velocity (i.e. natural acceleration); for the same cause cannot have two separate effects, while Fabri makes it clear that we should consider conservation as equivalent to production, therefore also demanding a cause. Fabri's expression "repetitive production" (*repetita productio*) of course indicates his general discrete approach, to be fully discussed later in this part. Concerning the answer to the obvious question which should be raised now – what *is* responsible then for the conservation of innate impetus? – Fabri supplies, in the corollary to theorem 11, a very brief but clear explanation: "Hence it must be conserved by another cause... whatever it will finally be, we shall at another time assert it is the First Cause."[11] Fabri's contention that God is responsible for the continuing conservation of impetus (in the absence of impeding obstacles) – echoing Descartes' ascription of the conservation of the "quantity of motion" to God – will be further discussed in the third part, which reveals Fabri's acceptance of the conservation of rectilinear motion.

Theorem 12 summarizes Fabri's view and – as Lukens remarks – "states the core of the theory":

> When a heavy body is in a free medium (*medium liberum*), through which it can descend, in the second instant new impetus is produced, and likewise in the third, fourth, fifth, etc. This is proved firstly, because in the second instant, there is the same necessary cause which was

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[9] "Impetus ille innatus, qui durat secundo instanti, conservatur ab aiiqua causa; est certum per Ax. 14, lib. 1, n. 1" (Fabri 1646, lib. 2, th. 10, p. 81).

[10] "Non conservatur a causa primo productiva. Probatur per Th. 144, lib. 1, alioquin non posset intendi ab eadem causa per Th. 146, lib. 1. Quippe conservatio nihil est aliud, quam repetita productio, ut constat" (Fabri 1646, lib. 2, th. 11, p. 81).

[11] "Hinc ab alia causa conservari necesse est, ut patet, eaque aplicata per Ax. 10, lib. 1; quaecumque tandem illa sit, nos aliquando causam primam esse dicemus" (Fabri 1646, lib. 2, th. 11, cor., p. 81).

> in the first instant,[12] and it is no longer impeded. Therefore it acts necessarily by axiom 12, book 1. Therefore it produces some effect. But this effect is not the impetus produced in the first instant, because that is not conserved by the cause that first produced it. Therefore it is new impetus.
>
> This is proved in a second way. The motion of heavy bodies increases in a free medium by hypotheses 1, 2, & 3. Therefore the impetus increases; because, since natural motion is the effect of impetus by theorem 5, the cause increases, by axiom 2, in the same proportion in which the effect (namely, a formal effect and of an exigence) increases, for motion is the effect of impetus by theorem 15 of book 1.
>
> It is proved in a third way, for a heavy body, falling from a larger height, inflicts a larger blow, by hypothesis 1, and therefore impresses a larger impetus on the struck body. But the impetus is produced toward the outside (*ad extra*) by other impetus, by theorem 42, book 1. Therefore, if the produced impetus increases, [this shows that] the producing impetus increases.[13]

Theorem 13 is very important, because it exemplifies the huge difference between Buridan's general conception of motion (and therefore also his specific view of free fall) and Fabri's theory, against Lukens's unhesitating assertion (following Drake's opinion) that the two are "hardly distinguishable" (see Section 9.2 below). Theorem 13 states that

> The impetus produced in the second instant in a free medium is conserved in the third, that produced in the third instant is conserved in the fourth, and so on, because they are not conserved by the initial productive cause...[14] nor does anything exact its destruction: not a contrary impetus, none of which of course is applied, nor a resistance of the medium, which indeed exists to some amount; but certainly not so much as to be able to entirely impede motion; for I suppose a free medium, therefore also that it does not destroy impetus; since as long as the effect endures, so does the cause; therefore there is nothing which would exact the destruction of that impetus.[15]

[12] As we recall, this cause is "the substance of the heavy body itself (*substantia corporis gravis*)", according to theorem 8 (beginning of Chapter 8 above).

[13] "Quando grave est in medio libero, per quod scilicet descendere potest, secundo instanti producitur novus impetus, itemque tertio, quarto, quinto. &c. Probatur primo; quia secundo instanti est eadem causa quae primo non magis impedita, eaque necessaria; igitur necessario agit per Ax. 12, lib. 1. igitur aliquem effectum producit; sed hic effectus non est impetus productus primo instanti, quia non conservatur a causa primo productiva per Th. 11. igitur est novus. Probatur secundo; crescit motus gravium in libero medio per hypoth. 1.2.3. igitur crescit impetus; quia cum motus naturalis sit ab impetu per Th. 5. qua proportione crescit effectus, scilicet formalis, & exigentiae; sic enim motus est effectus impetus per Th. 15, lib. 1. eadem crescit causa per Ax. 2. Probatur tertio, quia corpus grave ex maiore altitudine cadens maiorem quoque ictum infligit per hypoth.1. igitur maior impetus imprimitur in corpore percusso; sed impetus ad extra producitur ab alio impetu per Th. 42, lib. 1. igitur si crescit productus impetus, crescit impetus producens" (Fabri 1646, lib. 2, th. 12, p. 82); Lukens's translation, with some changes (Lukens 1979, p. 156).

[14] According to theorem 11 (see Chapter 8 above).

[15] "Impetus productus secundo instanti in medio libero conservatur tertio, & productus tertio conservatur quarto, atque ita deinceps; quia scilicet nec conservantur a causa primo productiva per Th. 144, libri: nec aliquid exigit destructionem; non contrarius impetus, quia nullus est applicatus, ut constat; non resistentia medii, quae quidem alicuius momenti est; sed non tanti, ut impedire possit motum omnino, ut constat; nam suppono liberum medium, igitur nec destruere impetum;

Fabri's ability to "abstract" all impediments to motion – especially air resistance – is significant. It is a far cry from Buridan's approach, which does not permit resistance-less motion, and explicitly objects to motion in a void.[16] Fabri's conception, which assumes an "ideal" motion that would occur under the assumption of void, is even more apparent in his remark later in *De motu naturali deorsum*, having completed the analysis of free fall: "if the heavy body were to descend in a vacuum, the abovementioned proportions would be preserved very accurately; i.e. because there is no impediment; but indeed if any impediment intervenes, no doubt they are not preserved accurately."[17] Such a conception, totally alien to Buridan's view, reveals the deep influence of Galileo, and is part of Fabri's "inertial" way of thinking (to be fully discussed in Part III).

The scholium of theorem 14 summarizes the properties of Fabri's two kinds of natural impetus (to be distinguished from violent impetus, which is produced from outside): innate impetus and acquired impetus.[18] Innate impetus, which Fabri identifies with *gravitas* ("*nam gravitas est ipse impetus innatus*")[19] is produced in the moment in which the body is produced, i.e. by the *generans*. It exists (and never diminishes) as long as the body exists, because it is never in vain, being responsible either for free fall (in the absence of any impediment), or for pressure downwards (on the impeding object, if such an object exists).[20] Proposition 10 of his mentioned above *De gravi et levi* (which belongs to the *Physica*) reasserts that "heaviness (*gravitas*) is not really distinguished from innate impetus",[21] and Fabri soon afterwards explains that when God created the elements, "He imprinted innate impetus in single points of the elements".[22] This issue is intimately connected to Fabri's elimination of absolute levity and acceptance of "absolute heaviness" discussed above; for in proposition 28, which states that "every body is heavy by absolute heaviness" (see Section 7.1 above), he argues that since *every* element is capable of receiving innate impetus – "and therefore also gravitas" (contrary, of course, to Aristotle's

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cum tamdiu duret causa quamdiu durat effectus, ut patet; igitur nihil est quod exigat impetus huius destructionem" (Fabri 1646, lib. 2, th. 13, p. 82).

[16]See beginning of Chapter 14 below.

[17]"Theorema 71: In vacuo si corpus grave descenderet, praedictae proportiones accuratissime servarentur; quia scilicet nullum esse impedimentum; at vero si aliquod intercedit impedimentum; haud dubie non servantur accurate" (Fabri 1646, lib. 2, th. 71, p. 115).

[18]"Observa... esse tres veluti species impetus. Prima est impetus naturalis innati. Secunda naturalis acquisiti. Tertia violenti" (Fabri 1646, lib. 2, th. 14, scholium, p. 83).

[19]Fabri 1646, lib. 2, th. 8, p. 81.

[20]"Innatus est qui vel a generante simul cum corpore gravi productus est, porro cum in corpore gravi duplex quasi proprietas sensibilis esse videatur, scilicet gravitas, seu pondus & motus deorsum... Ex his dicendum est hunc impetum nativum nunquam destrui, quia nunquam est frustra, habet enim semper aliquem effectum" (Fabri 1646, lib. 2, th. 14, scholium, p. 83).

[21]"Gravitas non distinguitur realiter ab impetu innato" (Fabri 1669–1671, tr. 1, lib. 4, prop. 10, p. 246).

[22]"Itaque ab initio, ubi Deus elementa creavit, singulis elementorum punctis impetus innatum impressit" (Fabri 1669–1671, tr. 1, lib. 4, prop. 12, p. 246).

fire, which is by definition light only) – it follows that every object is *ipso facto* heavy.[23]

Acquired impetus is created only when free fall occurs, that is in the absence of an impediment to downward motion. Fabri emphasizes that it is "produced by the same intrinsic principle" that produces the innate impetus, namely the substance of the body.[24] As Lukens sums up, "it is called 'natural' because it is produced by an intrinsic principle, and 'acquired' because it is not innate. It differs from the innate in that it can be destroyed by a resisting body, and can be directed along any line. Innate impetus is never destroyed and is always directed downwards".[25] Fabri's subsequent analysis – resulting in the law of natural numbers – explains the way in which this "acquired impetus" increases. Theorem 15 relates the production of natural impetus (i.e. innate and acquired impetus combined) to acceleration: "Natural impetus of a heavy body becomes more intense (*intenditur*) while it descends in a free medium"; Fabri explains this by using his abovementioned statement that the cause which initially produced innate impetus (substance) is not to be regarded as the cause responsible for its conservation, therefore this cause is "free" to have a different effect: to continually augment the initial impetus by a repetitive addition of an impetus unit.[26]

Now Fabri establishes that free fall involves uniform acceleration. He first claims that "in equal times equal impetus is produced", assuming the same necessary cause and the same impediment, then that "in the same proportion that impetus increases, the motion is accelerated, because in the same proportion that the cause increases so does the effect" and concludes that in equal times of descent a heavy body acquires equal moments (i.e. additions) of velocity.[27] In these three theorems Fabri relies on axioms 2 and 3 (formulated in the beginning of *De motu naturali deorsum*) that relate causes to effects generated in time: axiom 2 claims that the effect increases

[23] "... praeterea tam unum elementum capax est impetum innati, quam aliud; igitur & gravitatis; igitur cum omne elementum sit grave, certe omne corpus, quod scilicet vel elementum est, vel ex elementis, grave est" (Fabri 1669–1671, tr. 1, lib. 4, prop. 28, p. 254). Interestingly, Fabri will use this insight in his explanation of the Eucharist (see Section 18.1, especially Note 28 below).

[24] According to theorem 8 of *De motu naturali deorsum*; see Chapter 8 above.

[25] Lukens 1979, p. 159. "Impetus naturalis acquisitus producitur ab eodem principio intrinseco; hinc dicitur naturalis: dicitur vero acquisitus, quia non est innatus; sed separatur a corpore gravi; quod semper eo caret, quamdiu quiescit... Porro impetus acquisitus in multis differt ab innato; primo quia destruitur a corpore resistente... Secundo, quia determinari potest ad omnem lineam" (Fabri 1646, lib. 2, th. 14, scholium, p. 83).

[26] "Impetus naturalis corporis gravis intenditur dum hoc ipsum descendit in medio libero" (Fabri 1646, lib. 2, th. 15, p. 84). See also Fabri's theorem 11, explained in Chapter 8 above.

[27] "Theorema 17: Aequalibus temporibus aequalis impetus producitur, si sit eadem applicatio, idemque impedimentum; probatur, quia causa huius impetus est necessaria; sed eadem causa necessaria aequalibus temporibus aequalem impetum producit.... Theorema 18: Qua proportione crescit impetus acceleratur motus; quia quae proportione crescit causa, etiam crescit effectus... Theorema 19: Hinc aequalibus temporibus in descensu corpus grave acquirit aequalia velocitatis, vel accelerationis momenta... igitur aequalia velocitatis momenta, vel incrementa" (Fabri 1646, lib. 2, ths. 17–19, p. 85. Lukens's translation, after some changes; Lukens 1979, p. 160).

in the same proportion in which the cause increases, "and vice-versa, if applied in the same way to the same subject" and axiom 3 that "the same necessary cause, unimpeded, applied to a fitting subject, produces an equal effect in equal times".[28] Lukens correctly remarks that in Fabri's analysis "natural acceleration is proven to be uniform not by appeal to experiment, but by cause and effect" (Lukens 1979, p. 160). Fabri indeed assimilates Galileo's novelties according to his abovementioned ideal of physics – reducing sensible effects to causes.

From here the way to the "natural numbers" law is not long. After dealing with properties of uniform motion,[29] Fabri returns to the analysis of natural uniform acceleration. He simply states that "in naturally accelerated motion new impetus is acquired", since the same necessary cause (the heavy body's substance) repeatedly acts, and "hence in single equal instants" – in which the same abovementioned cause acts – "equal new impetus is acquired". "Hence", adds Fabri, "in single instants the impetus becomes more intense in this motion, since in single instants new [impetus] is produced, and the prior conserved, to which it is added, it becomes more intense." Consequently, "hence in single instants the impetus increases and becomes more intense equally... Therefore the speed of the motion increases equally in single instants".[30]

Therefore, explains Fabri in theorem 37, "impetus increases according to an arithmetical progression, for single instants add equal impetus"; the speed, continues Fabri in the next theorem, "increases in the same way, since in single instants equal moments [i.e. additions] of velocity are acquired, by axiom 2 and theorem 36".[31] Fabri is only one step away from arriving at his "natural numbers" law: he needs to show that the increase of velocity according to an arithmetical progression entails an increase of distance according to an arithmetical progression. Fabri easily proves this, for his discrete analysis assumes that during each instant the speed is uniform: as I explained before (see theorem 13, discussed in Chapter 8 above), this assumption is alien to Buridan's concept of motion, forbidding motion devoid

[28] "Axioma 2: Qua proportione crescit causa, eadem crescit effectus, & vicissim, si eodem modo eidemque subjecto sit applicata... Axioma 3: Eadem causa necessaria non impedita subjecto apto applicata aequalibus temporibus aequalem effectum producit" (Fabri 1646, lib. 2, axs. 2–3, p. 75. Lukens's translation, after some changes; Lukens 1979, p. 145).

[29] Fabri 1646, lib. 2, ths. 20–32, pp. 85–87. See also Lukens 1979, pp. 162–164.

[30] "Theorema 33: In motu naturaliter accelerato impetus novus acquiritur singulis instantibus; Probatur quia singulis instantibus est eadem causa necessaria, igitur singulis instantibus aliquem effectum producit... Theorema 34: Hinc singulis instantibus aequalibus novus impetus aequalis acquiritur... Theorema 35: Hinc singulis instantibus intenditur impetus in hoc motu; cum singulis instantibus producatur novus, & prior conservetur, cui cum addatur, intenditur... Theorema 36: Hinc singalis instantibus aequaliter crescit & intenditur impetus... igitur aequaliter etiam singulis instantibus crescit velocitas motus" (Fabri 1646, lib. 2, ths. 33–36, p. 87. Lukens's translation; Lukens 1979, p. 165).

[31] "Theorema 37: Hinc crescit impetus iuxta progressionem arithmeticam; cum singula instantia aequalem impetum addant... Theorema 38: Eodem modo crescit velocitas, quia singulis instantibus aequalia acquiruntur velocitatis momenta per Ax.2. & per Th.36" (Fabri 1646, lib. 2, ths. 37–38, p. 88).

of resistance (and therefore uniform), but fully compatible with Fabri's "inertial" outlook. So Fabri can rely (in theorem 40) on one of the theorems he has developed for uniform motion: theorem 28, which states that if two uniform motions occur in equal times, then the spaces traversed are to each other as the velocities, and may easily conclude that "hence the space increases equally in single equal instants".[32] Finally Fabri is entitled to assert that

> Hence the spaces increase in single equal instants according to an arithmetical progression, because space increases as the speed... and speed as the impetus... and this according to an arithmetical progression... Hence the spaces acquired in single instants are as the series of numbers which compose the simple progression, 1, 2, 3, 4, 5, 6, etc.[33]

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[32] Fabri 1646, lib. 2, th. 28. p. 86; Fabri 1646, lib. 2, ths. 39–42, p. 88. Theorem 42 claims: "Hinc quodlibet spatium crescit aequaliter singulis instantibus aequalibus; quia spatia crescunt ut motus, seu ut velocitates; hae crescunt aequaliter singulis instantibus aequalibus per Th. 36".

[33] "Hinc spatia crescunt singulis instantibus aequalibus secundum progressionem arithmeticam; quia crescit ut velocitas per Th.40. haec ut impetus per Th.38. hic demum iuxta progressionem arithmeticam per Th. 37... hinc spatia acquisita singulis instantibus sunt ut series numerorm, qui componunt progressionem simplicem, scilicet 1.2.3.4.5.6. &c" (Fabri 1646, lib. 2, th. 43, p. 88. Lukens's translation; Lukens 1979, p. 175).

Chapter 9
Fabri's Discrete Analysis

We have already seen that Fabri's analysis implies a discrete approach, since the accumulation of impetus (and consequently also of velocity and space) occurs within consecutive "instants" of time, i.e. discrete units, while assuming that during each such unit the speed is uniform. In the scholium of theorem 36, i.e. soon before completing the deduction of the "natural numbers" law of fall, Fabri fully discloses this important aspect of his theory:

> You will observe that the phrase "in equal instants" was used above; the reason is that the nature of time cannot be explained other than by finite instants as I will demonstrate in the *Metaphysica*. Whatever it may be, I call an instant that whole time in which something is produced all at once (*simul*), whether it be larger or smaller... Therefore that whole time in which the first acquired impetus is produced I call the first instant of motion. Equal times follow this one.[1]

In this chapter I shall first examine Fabri's basic concept of a "finite" (or "physical") instant according to his *Metaphysica*, which will turn out not to be an entirely discrete entity after all. Then I intend to refute the claim of Lukens and Drake that Fabri "inherited" his discrete mathematical approach from the fourteenth century pioneers of impetus theory, Jean Buridan and Albert of Saxony.

9.1 The Concept of Physical Instant

Fabri arrives at his notion of an "instant" after examining the nature of time in book 9 of his *Metaphysica*, entitled "On time and duration" (*De tempore & duratione*). At the very beginning of this book Fabri defines "duration":

[1] "Observabis dictum esse supra *instantibus aequalibus*, quia temporis natura aliter explicari non potest, quam per instantia finita, ut demonstrabimus in Metaphysica; quid quid sit, voco instans totum illud tempus, quo res aliqua simul producitur, sive sit maius, sive minus... Igitur totum illud tempus, quo producitur primus impetus acquisitus, voco instans primum motus; cui aequalia deinde succedunt tempora" (Fabri 1646, lib. 2, th. 36, scholium, p. 87; Fabri's emphasis).

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> *Duratio* is a principle of existing in time (*ratio existendi in tempore*). I am not saying that it is something distinct from the thing which is in time, or from time itself; I call *duratio* only a principle of existing in time. Since a concrete thing is in time, i.e. is now, after, before, for so long etc., it has a formal cause of its being in time, which I call *duratio*, by which a certain thing is said to be now, before, after etc.[2]

The nature of "duration" is clearer when we compare it to conventional Aristotelian time. The second definition of the chapter *De tempore & duratione* explains:

> Aristotelian Time (*tempus Aristotelicum*) is the number of motion in respect of before and after...[3] It is the multitude or collection of flowing parts of motion; i.e. of those parts which succeed each other by a continuous flux; so that one of them is before, and the other afterwards: it is an extrinsic time, which is applied to measure all durations. For if you would ask about someone, "how much did he live", or (which is the same thing) "for how long did he endure", it would be answered immediately, "he lived such a number of years", i.e. such a number of revolutions completed by the prime mover while he lived.[4]

So duration is the abstract and intrinsic formal cause (or principle), i.e. *ratio formalis*, of whatever exists in a definite time, while *tempus* itself is an external entity dependent on motion (in accordance with Aristotle's conception) and used to measure duration. In the first three propositions Fabri wants to establish duration as a sort of an "objective" entity, by claiming that even a cessation of every motion within the universe, which would mean stopping (Aristotelian) time, would not entail halting duration. The first one claims that "if there were no motion, there would be no Aristotelian time", and the second one simply states "Aristotelian time exists".[5] The third proposition declares:

> Except for Aristotelian time, explained above, which designates only a relation of a flowing measure, there exists another duration. It is proved, because having removed all actual motion – and [therefore] time (according to the first proposition) – if God conserves me, I shall yet endure; and I can endure more, or less; therefore there remains another duration.[6]

[2] "Duratio est ratio existendi in tempore. Non dico esse aliquid distinctum, vel ab eo quod est in tempore, vel a tempore ipso; sed tantum appello durationem, rationem existendi in tempore; quippe concretum hoc esse in tempore, esse nunc, post, ante. tamdiu. & c. habet raionem formalem huius esse temporis, quam voco durationem, qua scilicet res aliqua dicitur esse nunc, ante, post & c." (Fabri 1648, lib. 9, def. 1, p. 352).

[3] This is indeed Aristotle's definition of time (*Physics* [Aristotle 1930], 4, 11, 219b1).

[4] "Tempus Aristotelicum est numerus motus secundum prius & posterius... Hoc est multitudo seu collectio partium motus fluentium; id est quarum una continuo fluxu alteri succedit; ita ut altera sit prior, altera posterior; hoc est tempus extrinsecum, quod scilicet ad mensuram omnium durationum adhibetur. Si enim quaeras de aliquo, quantum vixerit, seu (quod idem est) quamdiu durarit [duraverit], statim respondetur, vixisse tot annos, id est tot revolutiones primi mobilis peractas esse, dum ille vixit" (Fabri 1648, lib. 9, def. 2, p. 352).

[5] "Propositio prima: Si nullus sit motus, nullum est tempus Aristotelicum... Propositio secundo: Datur tempus Aristotelicum" (Fabri 1648, lib. 9, props. 1–2, pp. 355–356).

[6] "Praeter tempus Aristotelicum supra explicatum, quod dicit tantum relationem fluentis mensurae, datur alia duratio, Probatur, quia sublato omni actuali motu, & tempore, per p. 1, si Deus me conservet, adhuc duro; posumque plus, vel minus durare, igitur superest alia duratio" (Fabri 1648, lib. 9, prop. 3, p. 361).

In proposition 5 Fabri reiterates this important point, and reemphasizes that "having removed all extrinsic motion, a thing will yet endure, as long as it is conserved by God".[7]

Fabri's notion of duration is reminiscent of the opinion of Descartes, who also detached duration from motion (or anything else external to the "enduring" object) by seeing it as an attribute of any created substance and claiming, in his *Principles of Philosophy* (1644), that "since any substance that ceases to endure ceases to be, there is only a distinction of reason between it [i.e., a substance] and duration".[8] Furthermore, because a finite substance cannot be the cause of its own duration, God – the infinite substance – must continually sustain it and maintain its existence (Garber 1992, p. 263); Fabri conveys here a very similar opinion. It is also worth mentioning that while denying the possibility of existence of time without motion was characteristic to Thomists, Scotists usually preferred to treat time as independent of motion (Ariew 2003, p. 166); the view of duration as such an independent – or "absolute" – concept of time echoes even in Newton's *Principia*.[9]

Fabri sees duration as an "action", while "action" is defined in the seventh book ("On Causes and Action") as "that by which an efficient cause acts actually".[10] Enduring in a certain time, then, is the result of an "action", while the "actor" of course is none other than God. "A created thing", says Fabri in proposition 10, "exists firstly – either now, or after, etc., i.e. in an intrinsic time – through the action by which it was produced at first". Proposition 11 claims that "A created thing exists secondly now, or after, i.e. it is conserved now, or after, by the action of its conservation". So conservation is nothing but a continuous act of producing, while both occur in some ordered unit of time ("first" or "second"): "Just as the action of initial production is a cause, by which I exist for the first time now; so the action of conservation is the cause, by which I exist for the second time, or conserved now; for as initial production relates to being at [the] first [time], so conservation relates to being [at the] second [time]".[11]

Now Fabri wishes to establish a close affinity between the concepts "action" and "instant", i.e. a unit of time which corresponds to each "action". In the twelfth corollary of proposition 11 he claims that "an action is changed in single instants, because

[7]"...sublato omni motu extrinseco, adhuc res durat, dum a deo conservatur" (Fabri 1648, lib. 9, prop. 5, p. 362).

[8]Quoted in Garber 1992, p. 263.

[9]"Absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly and by another name is called duration. Relative, apparent, and common time is any sensible and external measure (precise or imprecise) of duration by means of motion"; Newton 1999, def. 8, scholium, p. 408.

[10]"Actio est, qua causa efficiens actu agit" (Fabri 1648, lib. 7, def. 4, p. 234).

[11]"Res creata primo est, vel nunc, vel post &c., id est in tempore intrinseco, per actionem, per quam primo producitur... Res creata secundo est nunc, vel post, id est conservatur nunc, vel post, per actionem sui conservativam. Patet ex dictis, nam quemadmodum actio primo productiva est ratio, per quam primo existo nunc; ita [actio] conservativa est ratio, per quam secundo existo, seu conservor nunc; nam ut se habet primo prouctiva ad primum esse, ita & conservativa ad secundum esse" (Fabri 1648, lib. 9, props. 10, 11, p. 365).

a permanent thing – existing in this instant – in the following instant might not still exist. And since existing now is terminating such an action, while [existing] after, [terminating] another [action]... certainly action changes in single instants, intrinsic to the enduring object itself". The following corollaries claim that any action occurs in an intrinsic instant and is "all at once actually" (*tota simul est actu*) and therefore is "actually indivisible in time" (*indivisibilis actu in tempore*). Furthermore, "hence action itself is its own intrinsic 'now', because it is 'now' by itself, and a thing itself is 'now' by that towards which it is terminated; for an action of an action does not exist (as I said)." Fabri apparently wishes to avoid here an endless regression of *actiones*; in any case, his final conclusion is that "hence any action is a physical instant, because from the point of view of time, it is actually indivisible... hence it is the same to exist in this instant, or in this 'now', and to exist by such an action".[12]

Fabri further explains that any single action, being actually discrete (or indivisible), has no duration "actually", while "a successive duration in act is only a series of many actions, succeeding each other in a continuous flow".[13] In the tenth corollary of proposition 12 Fabri finally clearly connects duration to physical instants:

> A duration of a permanent thing is none other than a continuous series of many physical instants; for since I exist now by an action, and after by an action, and likewise before and in any other time by an action, and since enduring (*durare*) is being now, and after etc., certainly I endure through a series of actions, therefore through a continuous series of instants.[14]

After establishing physical instants as the components of duration, Fabri continues to examine the properties of the physical instant, and claims that "given any physical instant, there can be a bigger one and a smaller one; because given any action, or duration, there can be a more perfect one".[15] He concludes that therefore "mathematical instants", i.e. those endorsed by Galileo's continuous treatment, are

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[12]"Duodecimo, singulis instantibus mutatur actio; quia res permanens existens hoc instanti, in sequenti nondum existat; & cum nunc existere, sit terminare talem actionem, post vero, aliam, ut constat ex dictis; certe singulis instantibus mutatur actio; scilicet intrinsecis ipsi rei duranti; Decimo tertio, hinc quaelibet actio uno tantum instanti est; scilicet intrinseco... Decimo quarto, hinc quaelibet actio tota simul est actu... Decimo quinto, hinc quaelibet actio est indivisibilis actu, scilicet in tempore... Decimo sexto, hinc ipsa actio est suum *nunc* intrinsecum, quia nunc est, per se ipsam; & per illam nunc est ipsa res, ad quam terminatur; nec enim (ut dixi) datur actionis actio... Decimo septimo, hinc quaelibet actio est instans physicum; quia in ratione temporis est indivisibilis actu; ut explicabo paulo post. Hinc idem est existere hoc instanti, vel in hoc *nunc*, ac existere, per talem actionem" (Fabri 1648, lib. 9, prop. 11, cors. 12–17, p. 367).

[13]"Vigesimo, nulla actio seorsim sumpta est successiva actu; quia quod successivum est actu, fluit per partes actu... sed unica actio non habet partes actu, scilicet durationis, per n. 12, 13, 14... Vigesimo primo, hinc duratio successiva actu est tantum series plurium actionum, continuo fluxu sibi succedentium" (Fabri 1648, lib. 9, prop. 11, cors. 20–21, p. 369).

[14]"Decimo, duratio rei permanentis nihil est aliud, nisi continua series plurium instantium Physicorum; cum enim existam nunc per actionem, & post per actionem, item ante, alias &c. per actionem, & cum durare, sit esse nunc, & post, & c. certe duro per seriem actionum, igitur per seriem instantium continuam" (Fabri 1648, lib. 9, prop. 12, cor. 10, p. 374).

[15]"Tertio, hinc dato quocunque instanti physico, dari potest maius, & minus; quia data quacunque actione, vel duratione, dari potest perfectior" (Fabri 1648, lib. 9, prop. 12, cor. 3, p. 371).

impossible: "[It] opposes the existence of a positive mathematical instant, because given [any] time, there can be a smaller one; but nothing smaller than a mathematical instant can be imagined".[16] Being "physical" and not "mathematical", given any instant a smaller one will always be found, no matter how small it is. The very definition of a "mathematical instant", according to Fabri, is an instant of which no smaller time "can be imagined, i.e. it is indivisible both actually and potentially".[17]

A physical instant, explains Fabri, is "actually indivisible intrinsically (*indivisibile actu intrinsece*)... hence it is all at once actually; i.e. it is not composed of parts which actually succeed one another".[18] Nevertheless, a physical instant is also divisible, from a certain point of view:

> A physical instant is divisible potentially in a certain way, namely extrinsically. Because although it cannot be smaller and bigger than itself, it can nevertheless be bigger than another one; hence it can be measured by many, and in a way "divided"; since a measure behaves (*se habet*) as if it divided the measured [thing] into any number of parts. But this is being potentially divisible extrinsically (*divisibile potentia extrinsece*).[19]

A mathematical instant, which is not acceptable according to Fabri, is indivisible both actually and potentially. A physical instant, on the other hand, is indivisible "actually intrinsically", but divisible "potentially extrinsically", i.e. it has a continuous aspect, though only "potentially" and "extrinsically" (a fact which allows us to find a smaller instant than any given one). To the reader who asks "whether an instant can be said to endure", Fabri answers: "it does not endure actually and intrinsically, but potentially; i.e. it can be measured by different smaller ones".[20] It will later be shown that Fabri uses this twofold nature of "physical instants" to incorporate Galileo's law of fall into his own physics. But first it will be necessary to refute the alleged medieval origin of Fabri's discrete mathematical analysis of free fall.

9.2 A Medieval Approach?

Stillman Drake and David Lukens contended that Fabri's discrete approach to free fall was nothing but a detailed account of a theory already existing in the Middle

[16] "Quarto, repugnat tamen dari instans Mathematicum positivum, quia dato tempore, potest dari minus; sed instanti Mathematico nihil potest excogitari minus" (Fabri 1648, lib. 9, prop. 12, cor. 4, p. 371).

[17] "Instans mathematicum est, quo nihil minus in ratione temporis excogitari potest; id est nec est divisibile actu, nec potentia" (Fabri 1648, lib. 9, def. 6, pp. 353–354).

[18] "Quinto, instans physicum est indivisibile actu intrinsece... hinc totum simul est actu; id est non constat partibus quarum una succedat alteri actu" (Fabri 1648, lib. 9, prop. 12, cor. 5, p. 371).

[19] "Septimo, instans physicum est divisibile potentia aliquo modo, scilicet extrinsece; quia licet non possit esse minus & maius se ipso, potest tamen esse maius alio. Hinc a pluribus mensurari, & quasi dividi potest; quippe perinde se habet mensura, atque si mensuratum in tot, vel tot partes divideret; sed hoc est esse divisibile potentia extrinsece" (Fabri 1648, lib. 9, cor. 7, pp. 371–372).

[20] "Quares utrum instans possit dici durare; Respondeo, non durare intrinsece actu; sed potentia; id est mensurari posse ab aliis minoribus" (Fabri 1648, lib. 9, prop. 11, cor. 21, p. 369).

Ages. Buridan, claims Drake, originally conceived the idea that natural acceleration comprises discontinuous "steps" with ever increasing velocities. But it was Albert of Saxony, in his commentary on Aristotle's *De caelo* who gave it (so claims Drake) a "mathematical formulation" on which the "prevailing view" – i.e. the discrete approach – was based.[21] Lukens remarks generally that Fabri's theory of free fall is "hardly distinguishable from Buridan's explanation of acceleration in fall", and deems Fabri's discrete view – following Drake – as "the full expression of Albert of Saxony's idea".[22]

It is important to examine this claim, consulting the explanations of Buridan and Albert concerning free fall. Here is the core of Buridan's theory of fall:

> From these [reasons] it follows that one must imagine that a heavy body not only acquires motion unto itself from its principal mover, i.e., its gravity, but that it also acquires unto itself a certain impetus with that motion. This impetus has the power of moving the heavy body in conjunction with the permanent natural gravity. And because that impetus is acquired in common with motion, hence the swifter the motion is, the greater and stronger the impetus is. So, therefore, from the beginning the heavy body is moved by its natural gravity only; hence it is moved slowly. Afterwards it is moved by that same gravity and by the impetus acquired at the same time; consequently, it moves more swiftly. And because the movement becomes swifter, therefore the impetus also becomes greater and stronger, and thus the heavy body is moved by its natural gravity and by that greater impetus simultaneously, and so it will again be moved faster; and thus it will always and continually be accelerated to the end. And just as the impetus is acquired in common with motion, so it is decreased or becomes deficient in common with the decrease and deficiency of the motion.[23]

According to Drake, Buridan's acceleration "is clearly successive, and not continuous, since at first only a single cause acts, and then afterward two causes act, one of them constantly and the other successively" (Drake 1974, pp. 50–51). George Molland, commenting on Drake's interpretation believes that Buridan's assertion that "from the beginning the heavy body is moved by its natural gravity only; hence it is moved slowly" in itself renders Drake's claim "cogent" (Molland 1982, p. 47). However, immediately afterwards Molland rejects Drake's argument, and explains that "other passages from the quotation suggest strongly that the natural heaviness produces impetus at precisely the same time as it does motion and that speed

[21] Drake 1974, pp. 48–49; 1990, pp. 32–43. See also Drake 1975a, b.

[22] Lukens 1979, p. 161, n. 48 and p. 175, n. 25. See also Drake 1974, pp. 50, 56.

[23] Clagett 1959, pp. 560–561; the parenthetical enclosures are Clagett's. This is his translation from *Iohannis Buridani Quaestiones super libris quattuor de caelo et mundo* (Buridan 1942, lib. 2, qu. 12, p. 180, ll. 15–29): "Et ex istis sequitur, quod necesse est imaginari quod grave a suo motore principali, scilicet a gravitate, non solum acquirit sibi motum, imo etiam acquirit sibi quendam impetum cum illo motu, qui habet virtutem movendi ipsum grave cum gravitate naturali permanente. Et quia ille impetus acquiritur communiter ad motum, ideo quanto est motus velocior, tanto ille impetus est maior et fortior. Sic ergo a principio grave movetur a gravitate sua naturali solum, ideo tarde movetur; postea movetur ab eadem gravitate et ab impetu acquisito simul, ideo movetur velocius; et quia motus fit velocior, ideo etiam impetus fit maior et fortior, et sic grave movetur a gravitate sua naturali et ab illo impetu maiore, simul; et sic iterum movetur velocius, et ita semper continue velocitatur isque ad finem. Et sicut ille impetus acquiritur communiter ad motum, ita communiter minoratur vel deficit, ad minorationem vel defectum ipsius motus".

and impetus are strictly proportional. Concentration on these passages would mean ruling out the quantum interpretation" (ibid.).

I agree with Molland. First of all, it should be noticed that Buridan himself uses, near the end of the quoted passage, the adverb *continue*. Besides, Buridan depicts heaviness as the initial cause of motion, but not only does he fail to anywhere portray this initial motion as a "step", i.e. entailing a uniform velocity occurring within a final amount of time, he does not even clearly describe the impetus as a "second cause" – responsible (according to Drake's interpretation) for an additional discontinuous increase of speed, i.e. creating the second "step". Rather, Buridan claims that the impetus is acquired "in common with motion", and only then causes the motion to increase, a process which in turn increases the impetus, and so on. Buridan does not describe a mechanism according to which an impetus is simply a cause of motion, while the increase of impetus (caused by another reason, *not* the increase of velocity itself!) immediately entails the increase of velocity; such a mechanism – suggested by Fabri (as we recall, he ascribes the increase of impetus to the substance, acting through time) – is indeed compatible to a "neat" discrete analysis. But in Buridan's suggested mechanism, impetus and motion (or velocity) are so hopelessly and circularly interwoven, that (as Molland suggests) such a simple discrete mathematical analysis is not only unwarranted by Buridan's text, but is completely incompatible to it. The only way in which Buridan's view – regarding impetus and motion as mutually dependent, i.e. *always* changing together (being "strictly proportional", in Molland's words) – seems reasonable is if we regard the process of free fall as a perfectly continuous one; for adopting a discrete approach, i.e. admitting "horizontal steps" in which neither motion nor impetus increases, implies that the two are not always mutually dependent, since there are intervals of time in which an increase of motion (which occurred just before the "horizontal" interval began) did not cause an increase of impetus or vice versa. I believe that this is what Molland means in his (valid) criticism of Drake's view.

Let us now consult Albert of Saxony's text, and check whether it could be seen as a "mathematical formulation" (in Drake's words) of a discrete theory of fall. Albert, in his commentary on Aristotle's *De caelo*, is anxious to make sure that the velocity of a falling body does not diverge, i.e. potentially approach infinity (when the time is finite).[24] So, Albert claims,

> Natural motion does not accelerate by double, triple, and so on in such a way that in the first proportional part of the hour it is a certain speed and in the second proportional part of the hour twice as fast, and so on. Nor also does it accelerate in such a way that after the first proportional part of space has been traversed, for example, the first half of the space, it would be a certain velocity, and after the second proportional part of space has been traversed it then would be a velocity twice as fast, and so on. For then it would follow that any natural motion at all, which would last through any time as small as you like or traverse any space as small as you wish, would attain before the end any degree at all of velocity. Now this is false. . . Therefore in the third conclusion it is understood that the speed is increased by double, triple, etc. in such a fashion that after some space has been traversed

[24] Clagett 1959, pp. 565–569.

> by this [motion], it has a certain velocity, and after a double space has been traversed by it, it is twice as fast, and after a triple space has been traversed by it, it is three times as fast, and so on.[25]

Albert describes here three possible ways of explaining how velocity increases during natural fall. According to the first one, which Albert rejects, the velocity is constant along every "proportional" part of time, and it increases with each part: i.e. if it is v_o in the first interval of time $t/2$ (t representing the overall time of fall), it becomes $2v_o$ along the second interval $t/4$, $3v_o$ along the third one $t/8$ and so on. This option is indeed a "discrete" one, since it supposes constant velocities along finite (i.e. non-zero) intervals of time; it is rejected by Albert. The second alternative, that the increase takes place "upon *completion* of the succeeding proportional parts of the distance traversed (e.g. $s/2$, $s/4$)",[26] is also rejected. This time, Albert's description is continuous, because contrary to the first alternative – in which the velocity is described as being constant (and successively increasing) "*in prima parte proportionali*, *in secunda parte proportionali*" etc. – the second option describes velocity as receiving specific values "*quando est pertransita prima pars proportionalis spacii*", "*quando est pertransita secunda pars proportionalis spacii*" (see Note 25 above) and so on: the use of the *perfectum* tense makes it clear that the second alternative discusses velocities reached *after* distances are traversed, and not *during* the passage. The third alternative is the only one not entailing a diverging velocity, and therefore is the one preferred by Albert: the velocity simply increases as the spaces increase, and like the second alternative, it regards "momentary" velocities reached only *after* spaces have been traversed, using the same verb and the same tense (*est pertransitum*).

Hence it is clear beyond any doubt that the third option, the one accepted by Albert, is not discrete but continuous. This is why we must reject Drake's contention to the contrary, probably relying on the translation he proposes to Albert's third (i.e. preferred) alternative: "When some space has been traversed, [the speed] is some amount; and when double space *is traversed*, it is faster by double; and when triple space *is traversed*, it is faster by triple; and so on beyond".[27] Drake mistranslated – twice in this sentence – the present perfect (*est pertransitum* = "has been

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[25] Clagett 1959, pp. 566–567; I have slightly altered Clagett's translation. The original Latin text (ibid., pp. 568–569): "Sed sciendum est quod motus naturalis non intendit per duplum, triplum, et cetera, sic quod in prima parte proportionali hore sit aliquantus, et quod in secunda parte proportionali hore sit in duplo velocior, et sic ultra; nec etiam sic quod quando est pertransita prima pars proportionalis spacii, puta prima medietas, quod tunc sit aliquantus, et quando secunda pars proportionalis spacii sit pertransita, quod tunc in duplo sit velocior, et sic ultra. Nam tunc sequeretur quod quilibet motus naturalis, qui per quantumcunque tempus parvum duraret vel quo quantumcunque parvum spacium pertransiretur, ad quemcunque gradum velocitatis pertingeret ante finem. Modo hoc est falsum... Et ideo tertia conclusio intelligitur, quod intenditur per duplum, triplum, et cetera ad istum intellectum, quod, quando ipso pertransitum est aliquod spacium, est aliquantus; et quando ipso est pertransitum duplum spacium, est in duplo velocior; et quando ipso pertransitum est triplum spacium, est in triplo velocior, et sic ultra".

[26] Clagett 1959, p. 657, my emphasis; "s" means the overall distance traversed.

[27] Drake 1974, p. 51. My emphasis.

traversed") as present simple (= "is traversed"). Furthermore, Albert – exactly like Buridan – soon describes free fall explicitly as a continuously (*continue*) occurring process.[28]

To sum up, the attempt to link Fabri's discrete approach with Buridan's or Albert's old theory of impetus seems dubious, if not impossible. As Molland appropriately observes, Fabri's "discrete approach arose not from his being an impetus theorist but from being of the seventeenth century" (Molland 1982, p. 48). Indeed, if we are looking for a possible source of Fabri's discrete analysis of fall, we should turn our attention not to the fourteenth century, but rather much closer to Fabri's own period: Isaac Beeckman, one of the pioneers of the "inertial outlook" which so much influenced Fabri.[29]

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[28] Clagett 1959, pp. 566, 569.

[29] On Beeckman's analysis of free fall, which like Fabri is discrete (but unlike Fabri, not only does it not use impetus, it even explicitly rejects this concept), see Clagett 1959, pp. 417–418, 666, 678; Damerow et al. 2004, pp. 29–40; Dijksterhuis 1961, pp. 329–333. See also Appendix below.

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Chapter 10
The Assimilation of Galileo's Theory

The issue of Fabri's attitude towards Galileo's law of fall – i.e. the "odd numbers rule", which states that in successive equal amounts of time a falling body passes distances according to the series 1, 3, 5, 7... – has been (relatively) extensively investigated.[1] However, it is my impression that historians have tended to overemphasize the differences between Fabri's view and Galileo's, and thus to underestimate – or underappreciate – just how far Fabri was willing to go in order to incorporate into his philosophical system the crucial novelties which Galileo had introduced into the theory of falling bodies. I have already mentioned the two main issues which Fabri (and many contemporaries) could not accept in Galileo's theory: 1. His analysis of the continuum (i.e. assuming "mathematical instants", in Fabri's jargon); 2. The refusal to seek the cause of free fall. I intend to show here how Fabri accepted highly important characteristics of Galileo's theory – the fundamental proportion $v \propto t$, the whole range of experimental results, and ultimately (assuming instants small enough) even Galileo's "odd numbers rule", despite having initially formulated an alternative rule. Furthermore, even in those two issues in dispute he approached Galileo as far as he possibly could (as I will explain). There is no escape therefore from concluding that although Fabri's theory of free fall cannot be described as "Galilean", nevertheless it should not be considered as a "mere opposition to Galileo's physics",[2] but rather as an assimilation (or interpretation) of it.

10.1 Galileo's Definition of Uniformly Accelerated Motion

Following the suggestion of Sagredo and Simplicio, that the speed of a falling body should be considered as proportional to the space acquired since the beginning of its fall ($v \propto s$) – an assumption "so popular since the time of Strato, Alexander of

[1] Especially in the writings of Lukens, Drake, Palmerino and Galluzzi mentioned above; see also Dear 1995, pp. 138–144.

[2] Lukens 1979, abstract (an unnumbered page).

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Aphrodisias, and others"[3] – Salviati (i.e. the mature Galileo) replies that he has "a very clear proof" that this assumption is "false and impossible", since it directly leads to the absurd conclusion that "motion should be made instantaneously". To prove that the assumption $v \propto s$ entails this absurd conclusion, Salviati relies on a proposition stated earlier (proposition II from his section "On Equable Motion"), which states that "if the spaces are as the speeds, the times will be equal" (Galilei 1989, p. 150), and argues that

> if therefore the speeds with which the falling body passed the space of four *braccia* were the doubles of the speeds with which it passed the first two *braccia*, as one space is double the other space, then the times of those passages are equal; but for the same moveable to pass the four *braccia* and the two in the same time cannot take place except in instantaneous motion. (Galilei 1989, p. 160)

There has been a fascinating and long debate over the correctness of this brief and elegant proof. It has been claimed against Galileo that his rejection of $v \propto s$ is not valid, because Proposition II, on which it is based, applies to uniform motion only, and therefore not to uniformly accelerated motion.[4] However, Drake has successfully demonstrated its validity and even ingenuity. He has shown that despite belonging to the section "On Equable Motion", proposition II – unlike other propositions included in that section – is *not* restricted by Galileo to uniform motion. Furthermore, Drake convincingly maintains that whereas proposition II refers to "overall" speeds (i.e. velocity in a strict Aristotelian sense), the quoted passage refuting $v \propto s$ discusses *instantaneous* speeds, which in any given instant are (if we assume $v \propto s$) twice as big in the 4 *braccia* space as in the 2 *braccia* interval. So how can Galileo apply here proposition II, which deals with "overall" velocities? As Drake explains, Galileo uses the principle of one-to-one correspondence, according to which any term within an infinite series "corresponds" to any term belonging to a "smaller" infinite series contained within the first.[5] Consequently, to every instantaneous velocity within the aggregate of degrees contained in the motion along 2 *braccia*, we can match a "corresponding" one, twice as big, in the motion along 4 *braccia*; thus the proportion of "overall velocities" would necessarily be identical to the proportion between two corresponding instantaneous speeds, and thus also to the spaces, and therefore (according to proposition II) the times would indeed become equal – obviously an absurd conclusion (which thus renders the absurdity of the underlying assumption, $v \propto s$).

Probably the first to attack Galileo on this point was the senior Jesuit Le Cazre, who between the years 1643–1646 served as the rector of the Jesuit College of Metz and in 1648 was appointed provincial of Champagne (Hellyer 2003, p. 28).

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[3] Clagett 1959, p. 555. Galileo himself still adhered to it in 1604; it should be noted though that Nicole Oresme, e.g., was ambiguous concerning the manner of velocity increase, while Buridan endorsed both $v \propto t$ and $v \propto s$ (ibid., pp. 554–555, 563). On Albert of Saxony's disputed opinion see Section 9.2 above.

[4] Drake 1973, pp. 49–64. See also Finocchiaro 1972; Cohen 1956.

[5] As Drake explains, this is a feature of infinite series alone. See Drake 1973, pp. 56–57.

Le Cazre, a person of "optimum talent", "optimum judgment" and "of great prudence and long experience",[6] rejected $v \propto t$ in favor of $v \propto s$, and arrived at the geometrical series 1, 2, 4, 8... for successive spaces.[7] Not only the content, but also the unpleasant tone of Le Cazre's critique deserves our attention (and might cast some doubt on his alleged "great prudence"). In his *Physica demonstratio* (1645), Le Cazre claims that Galileo's theory rests upon false principles which are "mere suspicions", "hardly probable conjectures" and "evident paralogisms" (Galluzzi 2001, p. 248). He continues, sarcastically referring to Galileo's *Accademia dei Lincei*, named after the Argonaut of Greek mythology renowned for his sharpness of sight:

> And yet it is remarkable how much Galileo would applaud himself on his (so he thinks) subtle, clear, evident and mathematical demonstration, which he exalts by wonderful praises over a whole page. However it is far more amazing (*multo adhuc mirabilius*) that a Lyncean philosopher and mathematician, the leader of the Lynceans, would be so blind in such daylight.[8]

Le Cazre now claims that the proposition Galileo used – proposition II from "On Equable Motion" – is valid only concerning uniform motions, and thus is not applicable to uniformly accelerated motion. He concludes that "therefore Galileo's assumption is false, and his entire reasoning is a mere paralogism".[9] However, as Drake has shown, even though proposition II belongs to a section dealing with uniform motions, it is nevertheless "of general applicability" (Drake 1973, p. 53).

Contrary to Le Cazre, Fabri – claiming (as we have seen above, in Chapter 8) that on equal times of descent a heavy body acquires equal additions of velocity – has in effect accepted Galileo's "definition" of uniformly accelerated motion, though owing to the discrete analysis favored by the Jesuit it would be more accurately formulated as $v_i \propto t_i$ (while i denotes the ordinal number of any instant). However, like his Jesuit colleague from Metz Fabri does not accept (or understand) Galileo's proof. And yet, contrary to Le Cazre, Fabri sees no need for contemptuous remarks, and simply maintains (in theorem 19) that this "is what Galileo assumed, as a definition, in the third dialogue on natural motion; which to my judgment should have been demonstrated, rather than supposed". Fabri immediately explains that in his own discrete analysis, the proportion $v \propto t$ (actually, $v_i \propto t_i$) is a natural and immediate consequence, for "by the proportion in which the impetus increases, so motion

[6] According to the *catalogous triennalis* for the province of Champagne of 1645 (Hellyer 2003, p. 28).

[7] Palmerino 2003, pp. 206–208. Fabri explicitly rejects Le Cazre's series in corollary 7 of theorem 61 (Fabri 1646, lib. 2, th. 61, p. 97).

[8] "Et tamen mirum quantum Galileus de hac (ut putat) subtili, clara, evidenti, ac mathematica demonstratione sibi applaudat, quam integra pagina mirificis laudibus exaggerat. Sed illud multo adhuc mirabilius, quod Lynceus Philosophus ac Mathematicus, Lynceorumque princeps, in tam aperta luce caecutiat"; Le Cazre 1645, pp. 8–9; see Drake 1973, p. 54, n. 5.

[9] "Assumptio igitur Galilei falsa est, et tota eius ratiocinatio merus paralogismus" (Le Cazre 1645, p. 9).

increases... but in equal times equal degrees of impetus are acquired... therefore [also] equal moments, or increments, of velocity".[10]

Fabri decisively and explicitly rejects – or rather, like most of his contemporaries, fails to understand – Galileo's principle of one-to-one correspondence. In theorem 61 of the second book of the *Tractatus* (to be discussed below), which denies Galileo's contention that a falling body passes through "infinite degrees of slowness" before arriving at a specific velocity,[11] Fabri claims that even having accepted Galileo's assumption of infinite instants contained within free fall, "still the propagation would not take place through all degrees of slowness, because there would exist some degree of slowness, which that series of degrees would not contain; for [a body] begins to move more slowly on an inclined plane than straight downwards in a free medium".[12] As Drake and Lukens have noticed, Fabri's assumption that the fall along an inclined plane necessarily contains "more" degrees of speed than free fall implies a rejection of Galileo's one-to-one correspondence principle.[13] If Galileo's refutation of $v \propto s$ had been presented to Fabri as lucidly as Drake was to eventually clarify it, the Jesuit would certainly have objected (according to the inclined plane example) that if we tried to match every velocity between the two sets contained in the 2 *braccia* space and the 4 *braccia* space, surely "gaps" would be left within the "bigger" set, i.e. the velocities contained in the motion along the longer interval. Galileo, realizing that these "gaps" disappear when we are dealing with infinite series, and that in any case regarding the infinite series corresponding to the 4 *braccia* space as "bigger" than the one corresponding to the 2 *braccia* interval is highly problematic, would have replied by citing Salviati's warning from the first day of the *Two New Sciences*: "In final conclusion, the attributes of equal, greater and less have no place in infinite, but only in bounded quantities" (Galilei 1989, p. 41).

10.2 The Convergence to Galileo's Odd Numbers Law

Analyzing Galileo's definition of uniformly accelerated motion from his discrete point of view (i.e. the proportion $v_i \propto t_i$), Fabri concludes that new impetus is

[10]"Hinc aequalibus temporibus in descensu corpus grave acquirit aqualia velocitatis, vel accelerationis momenta; hoc ipsum est quod definitionis loco Galileus in dialogo tertio de motu naturali assumit; quod tamen meo iudicio fuit ante demonstrandum quam supponendum; quare sic demonstramus, qua proportione crescit impetus, crescit motus per Th. 18, sed temporibus aequalibus acquiruntur aequales impetus gradus per Th. 17, igitur aequalia velocitatis momenta, vel incrementa" (Fabri 1646, lib. 2, th. 19, p. 85).

[11]For example, in Galilei 1953, p. 34.

[12]"Licet essent infinita instantia, non fieret adhuc per omnes tarditatis gradus haec propagatio; quia daretur aliquis gradus tarditatis, quem non comprehenderet haec graduum series; nam incipit moveri tardius in plano inclinato quàm in libero medio recta deorsum, ut constat" (Fabri 1646, lib. 2, th. 58, p. 96).

[13]Lukens 1979, pp. 220–222, Drake 1989, pp. 77–79.

acquired "in single equal instants", since a "necessary cause" (the substance of the falling body) continually acts, and thus each instant produces an extra unit of velocity and therefore an extra unit of space (see Chapter 8 above). Now Fabri develops a discrete "mirror image" of Galileo's continuous discussion. Following Galileo's section "On Equable Motion" (Galilei 1989, pp. 148–153), Fabri presents 13 theorems concerning uniform motion,[14] and as an answer to Galileo's ("continuous") subsequent section "On Naturally Accelerated Motion", Fabri presents his own (discrete) analysis "Dissertation on Naturally Accelerated Motion".[15] Fabri shows that Galileo's "mean speed rule",[16] and "double-distance rule",[17] are equally valid in his discrete analysis.[18] Furthermore, Fabri reveals that he accepts Galileo's experimental results lock, stock and barrel. He explains that Galileo has offered, for substantiating his law, three experiments: vertical free fall, motion on the inclined plane and motion of pendulums. Fabri emphasizes that "many very serious writers, experts in philosophy as well as mathematics, often tested this [i.e. vertical fall] using sense perception (*sensu*), repeating their experiments ad nauseam".[19] Now Fabri takes pains to show that assuming extremely small instants, in which his "law of natural numbers" is valid, in sensible intervals of time (which include huge numbers of minute "instants") his law is indistinguishable from Galileo's "law of odd numbers", i.e. the series 1, 3, 5, 7... for successive distances passed in consecutive units of time. In the Appendix to this book, "The Proof of Convergence to Galileo's Law of Fall", it is shown how Fabri proved the "convergence" of his law of fall to Galileo's, using a very problematic property of his "natural numbers" series: the lack of scalar invariance, i.e. its (physically unacceptable) dependence on time units. It should be added that following this proof Fabri abandons his simple assumption of equal consecutive instants (on which his discrete analysis depends), and argues that new degrees of speed are acquired not in equal minima of time, but rather in equal minima of space, which entail gradually shrinking instants: as a consequence his theory becomes more and more complicated, and in the end he even resorts to irrational sequences.[20] This complication led to a severe (and partly justified) criticism

[14]Fabri 1646, lib. 2, ths. 20–32, pp. 85–87.

[15]Fabri 1646, lib. 2, th. 61, pp. 98–112.

[16]"The time in which a certain space is traversed by a moveable in uniformly accelerated movement from rest is equal to the time in which the same space would be traversed by the same moveable carried in uniform motion whose degree of speed is one-half the maximum and final degree of speed of the previous, uniformly accelerated, motion" (Galilei 1989, p. 165).

[17]If, following naturally accelerated motion (lasting for time AC), a body continues "to be moved with the same degree of speed BC, without accelerating further, then in the ensuing time CI it would pass a space double that which it passed in the equal time AC with degree of uniform speed EC, one-half the degree BC" (Galilei 1989, p. 168).

[18]Fabri 1646, lib. 2, th. 46, p. 91 and lib. 2, th. 60, p. 96.

[19]"...nam revera multi sunt, iique gravissimi auctores in rebus tum philosophicis, tum mathematicis versatissimi, qui saepius sensu ipso probarunt, repetitis usque ad nauseam experimentis" (Fabri 1646, lib. 2, th. 61, p. 99).

[20]Fabri 1646, lib. 2, th. 61, pp. 109–114.

by the French mathematician Jaques Alexandre Le Tenneur.[21] I shall not discuss here this further complication of Fabri's theory; it is worthwhile noting though that beginning with theorem 70, when Fabri starts to discuss motion in a medium, he returns to the simple "equal instants" assumption.

Fabri's "Dissertation on Naturally Accelerated Motion" appears immediately after theorem 61, which (as mentioned before) states the core of Fabri's objection to Galileo's "continuous" approach to velocity: "naturally accelerated motion", explains Fabri, "is not propagated through every degree of slowness". Accordingly, corollary 6 rejects Galileo's odd number rule.[22] And yet, it was just explained that Fabri's "Dissertation on Naturally Accelerated Motion" shows the convergence of Fabri's law to Galileo's. It is therefore worth observing Fabri's corollaries to this long dissertation; the first two in effect undermine Fabri's decisive objection to Galileo's assumptions of infinite "mathematical" instants and "infinite degrees of slowness":

> Corollary 1: Although there are not infinite parts of time, nevertheless in practice they behave as if they were infinite; since although they are finite, they cannot be counted.
>
> Corollary 2: Although there are not infinite degrees of slowness... but a finite number; in practice they behave as if they were infinite; because the first (and the smallest) cannot be distinguished from all the others.[23]

The third corollary summarizes Fabri's effort to assimilate Galileo's law of fall:

> Corollary 3: Although Galileo's hypothesis is false according to the hypothesis of finite instants (for a new increase of speed occurs in single instants),[24] nevertheless physically speaking it behaves as if it were true; because although it cannot be tested except in sensible parts of time, surely, since any sensible part contains almost innumerable instants, in which the propagation occurs, there cannot exist a sensible difference between the two [hypotheses]. Therefore the denticulated line[25] behaves physically, i.e. sensibly, as if it were straight... In the common opinion in which it is said that time consists of actually infinite parts, Galileo's progression can stand. Therefore, here is the key to the difficulty: the simple [natural numbers] progression is based on a physical principle, not on experiment; the progression of odd numbers is based on experiment not a principle. We combine the two,

[21] See Lukens 1979, pp. 211–223; Palmerino 2003, pp. 199–204.

[22] "Theorema 61: Motus naturaliter acceleratus non propagatur per omnes tarditatis gradus... Corollarium 6: Sexto reiicies illorum sententiam, qui volunt accelerationem motus naturalis ita fieri, ut spatia temporibus aequalibus acquisita sequantur seriem numerorum imparium 1.3.5.7.9.11.13. &c. & spatia sint ut quadrata temporum" (Fabri 1646, lib. 2, th. 61, pp. 96–97).

[23] "Corollarium 1: Etiamsi non sint partes infinitae temporis; in ordine tamen ad praxim eodem modo se habent, ac si essent infinitae; quia licet finitae sint, numerari tamen non possunt. Corollarium 2: Etiam si non sint infiniti tarditatis gradus, ut constat ex dictis, sed finiti; in ordine tamen ad praxim eodem modo se habent, ac si essent infiniti; quia non potest distingui primus, & minimus ab omnibus aliis" (Fabri 1646, lib. 2, th. 61, cors. 1–2, p. 108).

[24] It is worth noting that the term "hypothesis" is used here in a modern conventional manner, contrary to its special meaning described earlier (see Chapter 2 above).

[25] The line containing discrete "steps".

> by principle and by experiment; for the first is transformed (*transit in*) to the second if sensible parts of time are assumed, and the second to the first – if ultimate instants are assumed.[26]

Corollaries 4–6 urge the reader (i.e. Fabri's College students) to essentially abandon the discrete approach, and implement Galileo's proportion $s \propto t^2$. Corollaries 4 and 5 explain that using this proportion, it is possible to find out the space covered within several units of time, knowing the space covered in one unit, and vice versa. Corollary 6 explains that "knowing the time, the covered space can be known; since the spaces are as the squares of the times; or knowing the space, the time can be known; since the times are as the square roots of the spaces".[27]

Furthermore, concluding the issue of free fall in vacuum, Fabri restates (in theorem 70) that "if equal sensible spaces are assumed, the times are almost as the square roots of the spaces; for since the spaces are sensibly as the squares of the times, certainly the times are as the roots of those squares, i.e. spaces". Fabri gives some examples to demonstrate the applicability of theorem 70, and winds it up by stating that this proportion should be employed when dealing with sensible spaces, and that "from now on, whenever it is useful, we shall employ it".[28] Fabri indeed keeps his promise to continue to "employ" Galileo's proportion. In the fourth (and last) appendix of the *Tractatus*, which discusses the "physical principal of the duplicate ratio", Fabri marvels at the "many natural effects" to which the "duplicate ratio" – i.e. the quadratic ratio – corresponds. The first example he gives is naturally accelerated motion, in which "spaces are traversed in keeping with a duplicate ratio,

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[26] "Corollarium 3: Licet hypothesis Galilei sit falsa in hypothesi instantium finitorum; nam singulis instantibus nova fit velocitatis accessio; physice tamen loquendo eodem modo se habet, ac si esset vera; quia cum non possit probari, nisi in partibus temporis sensibilibus; certe, cum quaelibet pars sensibilis innumera fere instantia contineat, in quibus fit progressio; differentia utriusque sensibilis esse non potest; igitur linea denticulata eodem modo se habet physice, hoc est sensibiliter, ac si esset recta... in communi illa sententia, in qua dicitur tempus constare ex partibus actu infinitis, progressio Galilei tantum locum habere petest; igitur haec esto clavis huius difficultatis; progressio simplex principium physicum habet, non experimentum; progressio numerorum imparium experimentum non principium; utramque cum principio & experimento componimus; prima enim si assumantur partes temporis sensibiles transit in secundam, secunda in primam, si ultima assumantur instantia" (Fabri 1646, lib. 2, th. 61, cor. 3, p. 108).

[27] "Corollarium 4: Cognito spatio quod percurritur in data parte temporis sensibili, cognosci potest spatium quod in duabus aequalibus vel 3, vel 4 &c. percurri potest. Corollarium 5: Similiter cognito spatio quod percurrit 4 secundis minutis, cognosces spatium, quod percurret 2. vel 1... Corollarium 6: Similiter cognito tempore cognosci potest spatium decursum; quia spatia sunt ut quadrata temporum; vel cognito spatio cognosci potest tempus; quia tempora sunt, ut radices spatiorum" (Fabri 1646, lib. 2, th. 61, cors. 4–6, pp. 108–109).

[28] "Si assumantur spatia sensibilia aequalia, tempora sunt fere in ratione subduplicata spatiorum; cum enim spatia sint ut quadrata temporum sensibiliter; certe tempora sunt, ut radices istorum quadratorum, scilicet spatiorum... igitur in praxi quae tantum fit in spatiis sensibilibus haec progressio adhibenda est, illamque deinceps, si quando opus est, adhibebimus" (Fabri 1646, lib. 2, th. 70, p. 115).

i.e. according to the squares of the times".[29] Thus Fabri, having proved that his law converges to Galileo's law (in "sensible" times), has in effect deserted his initial "discrete" assumption that the traversed spaces behave according to the simple natural numbers series.

It is important to emphasize that Fabri's rejection of Galileo's "continuous" treatment of velocity – exemplified by the Jesuit's opposition to the principle of one-to-one correspondence (expressed in his view regarding acceleration along inclined planes) – did not prevent him from ultimately assimilating Galileo's ("sensible") law of fall, but surely should prevent us from defining Fabri's outlook as "Galilean".

However, it seems to me equally important to reject Drake's interpretation of Fabri's rejection as representing an inherent opposition between Galileo's "modern" continuous approach and a "conservative" scholastic "discrete" one (of which Fabri is, allegedly, a seventeenth century typical representative; see Section 9.2 above). We have already seen that Fabri's discrete analysis cannot be seen as a continuance of a medieval tradition; the discrete approach, as well as the controversy over Galileo's bold assertion that a body passes through "infinite degrees of slowness", are issues belonging to the seventeenth century. As Palmerino has shown, Galileo's statement raised many objections, and was contested not only by "conservatives": figures like Descartes, Gassendi, Roberval and Mersenne flatly rejected this assertion, labeled by the latter "*fundamentum Galilaei*" (Palmerino 1999, p. 322). The reason for this objection – as Palmerino observed – was not any dichotomy between "modern" and "medieval" attitudes (as Drake asserted), but rather the unavoidable tension between "mechanistic" philosophy, that wishes to explain nature in terms of impacts (i.e. discrete changes in velocity), and Galileo's "mathematical" (continuous) approach. This tension between "discrete physics", and "continuous mathematics", has already been described by Richard Westfall as "the apparent incompatibility between the demands of mathematical mechanics and those of the mechanical philosophy of nature".[30] For example, in a letter to Mersenne from June 1631, Descartes rejected the contention that the velocity of a falling body was "at the first instant the slowest that can be imagined and that it increases always uniformly thereafter"; this clearly stood against his basic explanation of gravity, i.e. "subtle matter" particles swirling in vortices and pushing, by consecutive (and necessarily discrete) impacts heavy bodies towards the center of the earth (Palmerino 1999, pp. 284–285).

[29]"De principio physico rationis duplicatae physicae: Vix credi potest quam multis effectibus naturalibus haec duplicata ratio affigatur, aliquos cursim indicabo ut verum germanumque illius principium statuatur. 1. In motu recto naturaliter accelerato, decursa spatia sunt in ratione duplicata temporum, id est ut temporum quadrata..." (Fabri 1646, app. 4, p. 443).

[30]Westfall 1971, p. 47; see also Palmerino 1999, p. 327.

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Chapter 11
Fabri's Assimilation Strategies

Lukens, who as mentioned above sees in Fabri's theory a "mere opposition to Galileo's physics", is not the only historian to express a sense of an "automatic dichotomy" which should inevitably exist (allegedly) between the physics of Galileo and a Jesuit like Fabri. Palmerino, who adopts a less extreme attitude than Lukens, still conveys a deep belief in such an "automatic dichotomy" in her conclusion that "in order to challenge the validity" of Galileo's law of fall "both Cazre and Fabri were forced to assume, in contradiction to the Aristotelian doctrine, that space and time are composed of indivisibles" (Palmerino 2003, p. 217). A similar view is apparent also in Paolo Galluzzi's account of the "second Galilean affair". Galluzzi in fact elaborates this "dichotomy" into a full-scale battle between the Copernican supporters of Galileo and the (inevitably anti-Copernican) Jesuits, although he makes a point of differentiating between those who (like Pierre Le Cazre) "tried to force the 'organic' supporters of the Galilean ideas, like Gassendi, into silence, with violent and threatening attacks, underlining the absolutely false character of those doctrines and their inevitable heretical implications" and "others, like Father Fabri", who "assumed a more skillful and subtle attitude".[1]

Feldhay has shown that the "first Galilean affair", i.e. the events surrounding Galileo's famous trial, should not be interpreted as an inherent conflict between rational science and an authoritarian church establishment, but should rather be examined from a "dialogical" point of view (Feldhay 1995, pp. 7–8). I believe that in light of the remarkable effort Fabri put into incorporating such a significant part of Galileo's theory of free fall – not to mention the common "Archimedean" background, including the abolition of levity – a similar approach should be adopted regarding the "second Galilean affair". Rather than presupposing this "automatic dichotomy" between Fabri's theory of free fall and Galileo's, and ignoring the similarities between them and especially the remarkable effort the Jesuit has put in to finally "converge" to Galileo's mathematical law of fall, it seems to me worth asking the following questions: how could Fabri allow himself to pass from a discrete approach to a fully continuous view, eventually entirely conforming to Galileo's

[1]Galluzzi 2001, p. 264. Le Cazre's attack against Galileo, described above (Section 10.1) indeed justifies Galluzzi's assessment of his criticism as "violent".

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analysis (for finite, i.e. measurable times)? And in any case, how did Fabri manage – despite incessantly claiming that free fall must have a cause (and complaining that Galileo had failed to provide one) – to eventually adopt a fully kinematic explanation, exemplified in the simple fact that his celebrated universal cause of motion in general, and naturally accelerated motion in particular (impetus) has no bearing whatsoever on the rate of fall? The remainder of this part will be devoted to these two issues, which constitute what might be called Fabri "assimilation strategies": i.e. techniques which enabled him to teach some of Galileo's most advanced novelties – the cutting edge of mid seventeenth century – in a Jesuit College, an establishment totally committed (at least nominally) to an Aristotelian, or Neoscholastic, philosophy.

11.1 Strategy No. 1: Discreetness Vs. Continuity

As Palmerino explains, "Lukens and Drake have maintained that the difference between Galileo's law of fall and Fabri's is not that the former implies a uniform growth of speed whereas the latter does not, but rather that the first, in contrast to the second, describes a continuous (and not a discrete) acceleration". She adds that "though this observation is, from a modern point of view, undoubtedly correct, there are good reasons for believing that Fabri would not have agreed with it" (Palmerino 2003, p. 203). Palmerino is correct in claiming that Fabri would object to describing his theory as "discrete", and she states a very important fact: Fabri never uses "the dichotomy between continuous versus discrete in order to characterize the difference between Galileo's theory of acceleration and his own" (ibid.). Indeed, Fabri himself states that

> There is no reason why you should say that it follows [from my account] that acceleration is not continuous, but discrete and interrupted; for it has to be considered as continuous, in the sense that the acquisition of a new degree of speed happens in single moments of time that are equal to the first instant.[2]

As Palmerino adds, Fabri has indeed rejected the theory of the Jesuit Rodrigo Arriaga, which assumed "intermissions" in motion (i.e. "moments of rest") to allow slower motions than those which involve "minimal speeds" (i.e. minimum space per a unit of time).[3] But I believe that the fact that Fabri did not consider his theory as "discrete" is connected not merely to his objection to Arriaga's theory of "interrupted" motion, but first and foremost to his overall conception of time (and therefore acceleration), which (to my mind) cannot be seen as strictly "discrete", despite the fact that Fabri's mathematical approach was indeed discrete; rather,

[2] "Nec est quod dicas, inde sequi accelerationem, non esse continuam, sed discretam, & interruptam; nam censeri debet continua, modo singulis temporibus, primo instanti aequalibus, nova fiat velocitatis accessio" (Fabri 1648, app. 3, p. 623). Palmerino's translation (Palmerino 2003, p. 203).

[3] Palmerino 2003, pp. 197, 203.

his overall conception should be considered as trying to reconcile the basic discrete "underlying reality" (exemplified in the law of natural numbers)[4] with the continuous phenomena which we perceive as "sensible effects" (represented by Galileo's odd numbers law).

Of course, there is some justification for depicting Fabri's conception as "discrete". In addition to the fact that Fabri did apply a discrete mathematical analysis, his claim (in the *Tractatus*) that an instant is a "whole time in which something is produced all at once (*simul*)" – meaning that a physical magnitude (like impetus) needs a finite time to be produced "all at once" – indeed hints at a really "discrete" entity of an instant.[5] It is no wonder then that there seems to be universal agreement among historians that Fabri's philosophy of motion (and particularly his concept of time) unequivocally "implied acceleration as a discontinuous process".[6] However, a discrete *mathematical analysis* of acceleration does not necessarily entail a discrete *concept* of time (or acceleration); as Carl Boyer has recognized, "mathematics is unable to specify whether motion is continuous, for it deals merely with hypothetical relations and can make its variable continuous or discontinuous at will" (Boyer 1949, p. 295). Furthermore, although Fabri's concept of time might be judged at first sight as discrete (according to his remark in the *Tractatus*), his detailed account of a physical instant (in his *Metaphysica*) – already described in Chapter 9 above – illustrates the inherent "dual" aspect of such an instant: for the Jesuit deems it actually indivisible ("intrinsically") but also potentially divisible ("extrinsically"), thus applying Aristotle's famous view of infinity (existing only "potentially", and not "actually")[7] to the intimately related issue of divisibility. Not only does Fabri emphasize that for any physical instant a smaller one can be found, but he also uses this argument to reject "mathematical instants" (those than which a smaller one cannot be found). So if the basic unit of time may be as small as we please, the difference between a "discrete" and "continuous" conception of time (and hence acceleration) is likewise rendered as small as we please; Fabri indeed implicitly uses this characteristic of instants in his proof that his discrete law converges to Galileo's (the "potential divisibility" of time permits Fabri to shrink the basic time unit as much as he wishes and thus approach a continuous analysis as much as he pleases).[8]

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[4]As we recall, Fabri considered his natural-numbers law as a rule "based on a physical principle (*principium physicum*)". However, as I have just shown, Fabri seems no longer to be interested in this "underlying reality", i.e. his "discrete" law, once having proved that it converged to Galileo's law.

[5]See beginning of Chapter 9 above. Fabri's phrase *simul* is somewhat confusing, since Fabri objects to infinitesimal instants, in which changes would indeed be rendered "all at once". Fabri in fact stays loyal to the Aristotelian scheme, according to which change (regarded by Aristotle as a process) necessarily occurs within a finite time.

[6]Galluzzi 2001, p. 253. To Drake, Lukens and Palmerino, who as we have seen accepted this observation, we can add Antonia LoLordo (LoLordo 2007, p. 162).

[7]*Physics* [Aristotle 1930], 3, 6, 206a8–18.

[8]This proof is explained in the Appendix below, "The Proof of Convergence to Galileo's Law of Fall".

Lukens, who tries to explain the difference between Aristotle's and Fabri's views toward time, correctly states that "for Aristotle, time like every continuum, is infinitely divisible and consists of parts that are likewise infinitely divisible". He is correct again in claiming that Fabri "asserts that the continuum of time actually consists of finite parts, potentially divisible". But I do not agree with Lukens's conclusion that the two views are opposed (Lukens 1979, p. 167). For according to Aristotle, a continuum is indeed "infinitely divisible", but since he claims that infinites exist only "potentially", and not "actually", what is the difference between claiming (like Aristotle) that time is infinitely (but necessarily "potentially"!) divisible, and asserting (like Fabri) that time "actually" consists of finite parts, which are themselves "potentially" divisible? These two views seem to me almost entirely equivalent. Both of them strongly deny Galileo's most fundamental assumption concerning the issue of continuity vs. divisibility: that a continuum consists of *actually* infinite "mathematical" indivisibles, i.e. that any finite time consists of ("mathematical", in Fabri's jargon) instants and that any finite distance consists of points. Fabri himself, referring to Aristotle's rejection of indivisible instants (in order to escape the conclusion of Zeno's paradoxes, according to which motion cannot exist), states, in his *Metaphysica*, that "Aristotle indeed denies that time is composed of instants, or mathematical moments, however he does not deny that it is composed of instants potentially divisible to infinity" and contends that "this potential or virtual divisibility cannot be explained in another way".[9]

My point is that Fabri's theory of "physical instants", which is not unequivocally discrete (for these instants are actually discrete but potentially continuous), is in fact hardly distinguishable from the Aristotelian view – accepted by most (though not all) scholastic philosophers – according to which time is infinitely divisible, but owing to the mere "potentiality" of the very concept of infinity the division of any continuum is a process which can never end (and thus may never yield *real* Galilean-style infinitesimals). John E. Murdoch, discussing infinity and continuity in later medieval philosophy, has emphasized that of all the points made by Aristotle in his treatment of the infinite, "undoubtedly the one most often repeated by the medieval philosopher was his denying the possibility of an 'actual infinite' of any sort and admitting only the 'potential infinite' that was associated with the infinite divisibility of continuous magnitudes. As Aristotle put it, any permissible infinite is not that beyond which there is nothing (for that would be a completed infinite *in actu*), but rather that beyond which there is always something (the infinite in *potentia*)".[10] This amounts exactly to Fabri's rejection of "mathematical" instants and his insistence that given any physical instant, a smaller one can be obtained. In other words, Fabri accepts the necessarily endless character of any division of a continuum, rendering its divisibility "potential".

[9]"Aristoteles negat quidem tempus componi ex instantibus, seu momentis mathematicis; non tamen negat componi ex instantibus divisibilibus potentia in infinitum; imo contendo hanc divisibilitatem potentia, seu virtute, alio modo explicari non posse" (Fabri 1648, lib. 9, prop. 12, cor. 25, p. 379).
[10]Murdoch 1982, p. 567.

Fabri explicitly uses his complex (some would say, obscure) attitude towards time in replying to the standard objection of "continuists" against "atomists", according to which a discrete approach strongly contradicts Euclidean (i.e. standard) geometry, since it is clearly irreconcilable, e. g., with the notion of incommensurable ratios between magnitudes. Fabri replies that his concept does not contradict the accepted understanding of the continuum, arguing that "being potentially divisible is nothing other than being actually indivisible or not containing distinct things, of which one can truly be separated from another, but only being able to correspond by coextension to distinct things"; his subsequent example reveals that "corresponding by coextension" means nothing but extrinsic potential divisibility, the property he has ascribed to physical indivisibles (of space, in this case): an indivisible "point of matter", explains Fabri, is "effectively" (i.e. actually) indivisible, nevertheless it "can correspond by coextension" to two other points of matter which have half its extension, to three other points which have only a third of the original extension and so on to infinity.[11]

With his intricate view of time, that attempts to reconcile between the discrete and the continuous – in a manner equivalent to Aristotle's attempt to harmonize the finite and the infinite – Fabri has managed to produce a sort of bridge between his basic "discrete" natural numbers law and Galileo's "continuous" odd numbers law. Lukens might appear to be reasonable in claiming that Fabri's somewhat obscure notions are "the kind of specious arguments that made Galileo remark that only second-rate mathematicians had ever tried to deal with problems of infinity and indivisibles" (Lukens 1979, p. 168). Furthermore, modern historians cannot be blamed for treating with suspicion Fabri's claim that his theory of motion is "continuous". But it seems to me that considering his basic conception of time – complicated and peculiar as it may appear – Fabri's refusal to admit that his theory of acceleration is discrete is not strange or suspicious at all. In fact, the ambiguity of his theory of time (as well as the problematic nature of his "proof of convergence", i.e. its "scalar variance"), should be seen as the price Fabri paid in order to incorporate Galileo's law of fall without entirely estranging himself from "conservative" physics. Fabri, not possessing modern methods of reconciling the discrete with the continuous (e.g. the mathematical concept of limit), could only resort to the old and cumbersome trick invented by Aristotle: the dichotomy actual/potential, which failed to impress Galileo (Galilei 1989, pp. 43–44). So contrary to the criticism (verging sometimes on ridicule) which is usually expressed by modern historians and which echoes Galileo's sentiments, it seems to me that Fabri should not be berated, but rather

[11]"...estre divisibile en puissance n'est autre chose qu'estre indivisibile actuellement ou ne contenir pas de choses distinctes, dont l'une puisse veritablement estre separée de l'autre, mais seulement pouvoir respondre par coextension à des choses distinctes. Par exemple, un point de matiere est indivisible effectivement, mais neantmoins il peut respondre par coextension a deux autres points de matiere qui auront une extension plus imparfaite en raison 1/2, et a 3, et a 4, et ainsy jusques a l'infiny"; Tannery et al. 1945–1988, vol. XII, p. 291. See also Palmerino 1999, p. 315.

commended for his resourcefulness and his ability to use (allegedly) obsolete ideas to incorporate important New Science achievements.

11.2 Strategy No. 2: Neutralizing Impetus

The second obstacle to the assimilation of Galileo's theory of free fall is the Pisan's well known refusal to discuss the cause of free fall. As is well known, Galileo's bold decision irritated many (probably most) of his contemporaries, Fabri being no exception: we have noticed him complaining that Galileo "did not prove those marvelous effects from physical principles, but only assented to some proportions from geometrical principles" (see Chapter 6 above). Descartes, in his famous criticism of the *Two New Sciences* in his letter to Mersenne from 1638, conveyed a similar attitude when he accused Galileo that "without having considered the first causes of nature he has only sought the reasons of some particular effects, and thus he has built without foundation" (Damerow et al. 2004, p. 350). Mersenne (probably following Descartes), as well as Gassendi and Kenelm Digby also emphasized the need to account "causally" for natural acceleration (though figures like Fermat, Hobbes and Roberval were less insistent on this requirement).[12]

Palmerino describes in detail the incompatibility of Galileo's mathematical (and continuous) approach with the "mechanist" view, which relies on a basic "model of impact" (whether the impacts are produced by "subtle matter", air particles or magnetic corpuscles) and necessarily involves external causes (and discrete mechanisms). She also explains how Mersenne was finally persuaded, especially by Descartes, that the assumption of an external cause for free fall cannot be reconciled with a continuous "mathematical" account, i.e. with Galileo's odd numbers law; accordingly Descartes rejected Galileo's attitude immediately, while Gassendi's attempt at such a reconciliation was doomed to failure.[13]

Fabri's position was different from the prevalent "mechanistic" mood, and (somewhat ironically) more readily capable of assimilating Galileo's law of fall. As I have shown, despite opting for a discrete mathematical analysis, the potential divisibility of time in effect allowed Fabri to "converge" to Galileo's continuous analysis. To this we must add Fabri's insistence – described in detail above – that free fall must be caused by an *internal* reason, not an external one, and thus his "causal" view, unlike the "mechanistic" conception, is not inherently contradictory to Galileo's continuous approach. Similarly, Galileo – while refusing to delve into the nature of the power which is responsible for free fall – nevertheless insists that "a heavy body has from nature an intrinsic principle of moving toward the common center of heavy objects" (Galilei 1989, p. 77), thus clearly aligning himself against "external" mechanists à la Descartes. Thus, contrary to Descartes' followers, Galileo – exactly like Fabri after him – retains Aristotle's notion of "natural

[12]Lolordo 2007, pp. 161–162.

[13]Palmerino 1999, pp. 273, 311–312.

motion", although limiting it to the downward motion of heavy bodies (i.e. rejecting levity), and deeming its cause "internal" rather than "external" (see Section 7.2 above).

However, the similarity between Fabri's and Galileo's conception of free fall is even more striking: Fabri not only (ultimately) accepted Galileo's law of fall, but also explicitly adopted, in his *Tractatus* as well as the *Metaphysica*, the important Galilean and anti-Aristotelian dictum, that all bodies fall (neglecting air resistance) exactly at the same rate.[14] Fabri's way of proving this far-reaching (totally anti-Aristotelian) assertion – essential to a kinematical, i.e. "weight free" analysis of motion – is pertinent to the issue at hand, for it involves deliberately eliminating impetus, the alleged cause of free fall, as a factor which has any effect whatsoever on the way a body falls. Axiom 13 of *De impetu* (the first book of the *Tractatus*) states that "the extension of a cause does not strengthen an effect inwards (*ad intra*)"; for example, "any part of a bigger fire does not have a more intense heat than any part of a smaller fire." Fabri concludes, concerning falling bodies: "I say the same about the heaviness of lead, etc.; and a pound of lead connected to another does not have a different heaviness than the heaviness that it has being separated." Fabri adds that as far as influence *outwards* (*ad extra*) is concerned, however, extension helps very much: "Thus a bigger fire diffuses its heat farther away; a heavier body falling inflicts a greater blow".[15]

Fabri's insight that a bigger extension – i.e. a greater amount of matter – serves to frustrate the motion of an object, and thus prevent an intensified moving cause (i.e. greater innate impetus) from producing a greater effect, seems to me highly important. It is a far cry from the view of Buridan, who claimed that the reason "why I project a stone farther than a feather" is "that the reception of all forms and natural dispositions is in matter and by reason of matter. Hence by the amount more there is of matter, by that amount can the body receive more of that impetus and more intensely" (Clagett 1959, p. 535). Fabri explicitly objects to this view (which regards matter as necessarily *assisting* motion, not frustrating it) by rejecting, in the scholium of theorem 62 of *De impetu*, "the argument of those who say that a body is capable of having a higher velocity because it has more parts of matter under the same quantity [i.e. a higher density]" and claiming that a large

[14]While discussing bodies falling in material media, in the second book of the *Tractatus*, Fabri conveys an even more "universal" view than Galileo, by claiming (against the latter) that things similar in shape and material but different in size fall exactly in the same manner in *any* given medium (Fabri 1646, lib. 2, th. 112, p. 128 and th. 113, p. 129). For Fabri's explicitly anti-Aristotelian and pro-Galilean support (in his *Metaphysica demonstrativa*) of the universal velocity of fall (in the void) see Part III, Section 14.3 below.

[15]"Extensio causae non intendit effectum ad intra. Quaelibet pars maioris ignis non habet calorem intensiorem, quam quaelibet pars minoris; idem dico de gravitate plumbi, &c; nec enim libra plumbi coniuncta cum alia habet diversam gravitatem ab ea, quam habet separata. Dixi ad intra; quia ad extra multum iuvat extensio; sic maior ignis longius diffundit suum calorem; corpus gravius cadens majorem ictum infligit" (Fabri 1646, lib. 1, ax. 13, pp. 10–11).

weight does not assist motion impressed from outside but rather inhibits it.[16] Fabri thus foreshadows the modern understanding that a feather travels less due to much greater air resistance and not because of its small quantity of matter. Fabri also remarks that a "bigger bulk" is "more suitable to impress motion, and less suitable to receive" it, while the opposite is true for a "smaller bulk".[17] Fabri's explanation that a bigger extension balances a more intense cause of motion (i.e. a greater innate impetus) is somewhat reminiscent of the Newtonian account for the same phenomenon (the non-dependence of gravitational acceleration on either size or density), i.e. "that the increased gravitational attraction to which more massive bodies are subject is exactly counterbalanced by their greater inertia, manifested as resistance to acceleration".[18]

Theorem 37 arrives at the same conclusion – uniform universal natural acceleration – from a different angle. It says: "A part of impetus received in a part of a subject does not exact motion of other parts of the same subject, even connected ones." Otherwise, claims Fabri, "one part of impetus would suffice to move a huge rock, which is absurd." Thus, continues Fabri, "just as one part of heat does not break up other parts of the subject, neither does impetus [affect other parts]." Fabri also supplies an "a-priori reason" for this: "Because impetus is not an efficient cause of motion. . . but only a formal cause. . . therefore if fulfils its formal effect only in the subject in which it exists."[19] Corollary 2 of theorem 37 claims:

> Hence a body heavier by itself (*per se*), at least of the same material,[20] does not fall faster than a lighter [body], as a leaden ball of 100 pounds [does not fall faster] than a leaden ball of one pound; because an impetus of one part does not help the motion of another; besides, 2 parts of impetus received in 2 parts of a subject will move them as easily as 100 [parts of impetus would move] 100 others. I said *per se*, because the resistance of the medium can vary.[21]

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[16]"Reice commentum illorum, qui dicunt corpus illud esse majoris velocitatis capax, quod plures habet partes materiae sub eadem quantitate. . . immo sit globus plumbeus 12 librarum, sit eburneus eiusdem diametri 2 librarum, v. g. haud dubie eadem potentia producet intensiorem impetum ineburneo" (Fabri 1646, lib. 1, th. 62, p. 40). Theorem 62 itself asserts that a small ball moving at a given velocity (say v_0) impresses on a bigger ball a less intense impetus, therefore a smaller velocity than v_0 (Fabri 1646, lib. 1, th. 62, p. 39).

[17]". . . sicut maior moles aptior est ad motum imprimendum, & minus apta ad recipiendum ita minor contra aptior est ad recipiendum, & minus apta ad imprimendum" (Fabri 1646, lib. 1, th. 47, scholium, p. 34).

[18]Gaukroger and Schuster 2002, p. 548, n. 26.

[19]"Impetus pars recepta in parte subiecti non exigit motum aliarum partium eiusdem subiecti, licet coniunctarum. Probatur 1. Quia alioquin una pars impetus sufficeret ad movendam ingentem rupem; quod absurdum est. 2. Sicut una pars caloris non resolvit alias partes subiecti; ita nec impetus. 3. Ratio a priori est; quia impetus non est causa efficiens motus. . . sed tantum causa formalis. . . igitur praestat tantum suum effectum formalem in eo subiecto, in quo est" (Fabri 1646, lib. 1, th. 37, pp. 28–29).

[20]Fabri is referring here to motion in any medium. He should have added that the heavier body must be with the same shape too (the following example indeed concerns balls); see Note 14 above.

[21]"Corollarium 2: Hinc corpus gravius per se, saltem eiusdem materiae, non cadit velocius, quam levius, uti globus plumbeus 100 librarum, quam globus unius librae plumbeus; quia scilicet

Thus Fabri uses (also) the notion of impetus as a formal (and not efficient) cause to explain why the rate of fall does not depend on the weight or size of the falling body, i.e. on any impetus whatsoever.[22] Fabri also utilizes here his method of "quantification" of impetus, which is reminiscent of Descartes' concept of "quantity of motion": in corollary 2 of theorem 33 Fabri explains that a given motive force pushes a big stone slowly and a small one quickly, because "the parts of impetus produced [by the motive force] are distributed in more parts of the subject in the bigger stone, and in less parts in the smaller; therefore each part of the smaller [stone] has more parts of impetus".[23] So the actual velocity of an object depends not on how many "parts of impetus" are in it, but on the "density" of them, i.e. on this number divided by the object's weight: if we treat then heaviness (*gravitas*) as a kind of an "inner motive force" which produces parts of impetus in proportion to the weight of the body, in order to measure the actual effect of the impetus (i.e. the velocity) – which as a formal cause influences only the parts which it informs – we would have to divide the number of "parts of impetus" into the number of "parts of subject" (i.e. weight) and thus we would obtain the same result for every falling object, regardless of its weight. This seems to be Fabri's way of thinking that connects the ideas of impetus as a formal cause, the distinction between influencing *ad intra* and *ad extra*, and the famous Galilean and anti-Aristotelian dictum that all bodies (in a void) fall exactly the same. In this way Fabri completely neutralizes impetus (or heaviness) as a determining factor concerning free fall and clears the way for his kinematical (discrete) mathematical analysis.

Should anyone claim that Fabri's explanations for uniform natural acceleration seem somewhat arbitrary and ad hoc, it might be pointed out – again, in the words of Gaukroger & Schuster – that "Classical mechanics never had any explanation of this equivalence of gravitational and inertial mass, and General Relativity reveals that it was one of the greatest lacunae in classical mechanics, for the equivalence held the key to the understanding of the connection between gravitation and inertia".[24]

We can now sum up this complex subject of falling bodies. By claiming at the very beginning of his analysis that the cause of free fall is internal, Fabri adopted the medieval impetus tradition and also Galileo's view, against Aristotle, many of his scholastic followers (notably Thomas Aquinas), and also the "mechanist" contemporary philosophers, who all wished to explain free fall using external causes. Following a discrete mathematical analysis, which has been shown in this part *not*

impetus unius partis non iuvat motum alterius: praeterea tam facile 2 partes impetus in 2 partibus subiecti receptae easdem movent, quam 100 alias 100. Dixi per se; nam diversa esse potest medii resistentia" (Fabri 1646, lib. 1, th. 37, cor. 2, p. 29).

[22] This is of course correct only in the case of free fall in vacuum. As for falling bodies in media, this phenomenon is now known to be much more difficult to analyze than Galileo, Fabri, or any other contemporary would have imagined.

[23] "Quia scilicet partes impetus producti distribuuntur pluribus partibus subiecti in maiori lapide, & paucioribus in minori; igitur singulae partes minoris habent plures partes impetus" (Fabri 1646, lib. 1, th. 33, cor. 2, p. 27).

[24] Gaukroger and Schuster 2002, p. 548, n. 26.

to originate from the medieval impetus tradition, Fabri developed his basic law of natural numbers. However, Fabri's mathematical analysis did not entail a discrete conception of reality: using the fact (unnoticed, or not appreciated enough by most historians) that his instant is not *really* discrete, Fabri could show (by a trivial arithmetical analysis) that his law of fall not only approximated, but truly converged, to Galileo's law of fall, under the assumption of tiny instants. Therefore, instead of sharing Palmerino's astonishment, that Fabri was "forced to assume in contradiction to the Aristotelian doctrine, that space and time are composed of indivisibles" in order "to challenge the validity" of Galileo's law of fall (see beginning of Chapter 11 above), we should first realize that despite implementing a novel (i.e. seventeenth century inspired) discrete mathematical analysis, Fabri's deep conception towards time and acceleration was more standard and less anti-Aristotelian than it might seem at first sight, and as he himself insisted, it should not be deemed "discrete" at all.[25] Following this, we should be astonished rather that Fabri, in order to *assimilate* the essentials of Galileo's theory of free fall, was willing not only to abandon Aristotle's basic rules concerning natural motion (the absoluteness of levity, the dependence of the rate of fall on weight), but also to adopt a peculiar twofold nature of time (actually discrete but potentially divisible) and emphasize the lack of scalar invariance of his physical law (thus allowing the convergence of his law to Galileo's). Even more astonishing is his willingness to give up impetus – allegedly the inevitable cause of every kind of motion – as having any effect on the downwards motion of bodies. It seems to me that Fabri – unlike, e.g. Gassendi – was rather successful in adapting his physics to Galileo's innovations (using mathematical "tricks" and the Aristotelian dichotomy between *actu* and *potentia*), but the price was a physical theory laden with dense and ambiguous explanations and inconsistencies (e.g., the status and role of impetus).

In the next part I shall demonstrate how Fabri used his notion of impetus, as well as the special causal relation between impetus and motion (discussed in Part I), to incorporate into his physics yet another building block of classical mechanics: Descartes' concept of conservation of rectilinear motion.

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[25] In fact, Fabri's standard views concerning the analysis of the continuum is exemplified by his rejection of the following assumptions of Galileo: 1. that any finite continuum contains an "actual" infinite of mathematical indivisibles; 2. the principle of one-to-one correspondence.

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Part III
Violent Motion

Chapter 12
Fabri and Conservation of Rectilinear Motion

As hinted earlier, one of the most interesting aspects in Fabri's physics is the wholehearted adoption of the important principle of conservation of rectilinear motion (henceforth designated as CRM) – a direct result of an impetus which is linearly oriented and tends to conserve itself in the absence of obstacles or hindrances, and the possibility of motion in a vacuum, in which this linear impetus is necessarily conserved.[1] CRM is often referred to as "inertia", but this problematic term is both anachronistic and misleading. The word *inertia* (originally meaning "laziness") was first utilized in a physical sense by Johannes Kepler, to mean a tendency of bodies to come to rest once they are set in motion (Bertoloni Meli 2000). It was subsequently used, in a different sense – meaning the reluctance of bodies in rest to be set in motion – by Descartes (Des Chene 1996, p. 307), and even by Fabri himself.[2] However, even confining ourselves to its post-Newtonian meaning, the concept of inertia is far more complicated than it might seem at first sight. This notion, as it is expressed in Newton's first law – "Every body perseveres in its state of being at rest or moving uniformly straight forward, except insofar as it is compelled to change its state by forces impressed" (*Principia* [Newton 1999], p. 416) – could be regarded merely as a "less important aspect of inertia" than his *second* law (Graneau and Graneau 2006, p. 28.); it is also clear that the classical (or Newtonian) concept of inertia cannot be fully expressed and understood without Newton's *third* law and his concept of force (Gabbey 1980, pp. 287–288). Therefore I shall refrain from ascribing to Fabri the "concept of inertia", and use instead the principle of CRM, which I define thus: "An object once moved in a certain direction, and henceforth affected by no other factor, will continue ad infinitum in its motion along that very direction with uniform velocity." It must be emphasized that from similar reasons,

[1] I have discussed this aspect (in less detail than here) in Elazar 2008.

[2] In theorem 62 of the first book of Fabri's *Tractatus physicus de motu locali* (1646) he explains that a force applied on a leaden ball will move it more slowly than the same force applied to a much lighter ivory ball (with the same diameter) because of some "laziness of matter" (*inertia materiae*) which inhibits motion: "sit globus plumbeus 12 librarum, sit eburneus eiusdem diametri 2 librarum, v.g. haud dubie eadem potentia producet intensiorem impetum in eburneo, ut patet experientia, & ratio constat ex dictis; quasi vero sit aliqua materiae inertia, quae motum respuat" (Fabri 1646, lib. 1, th. 62, p. 40). See also Section 11.2 above.

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it is not possible to claim that Descartes' physics (let alone Galileo's) is genuinely "inertial".

Be that as it may, there seems to be a uniform consensus among historians over the assertion that in Fabri's mechanical thought there is no place for CRM (usually simply designated by them as "inertia"). Before returning to a detailed analysis of Fabri's theory, it is important to address these claims, which are still prevalent. Annelise Maier seems to have been the first to address this matter and to maintain the alleged incompatibility between Fabri's physics and CRM. Maier, who strongly (and convincingly) objected to Pierre Duhem's attempt to portray Buridan's impetus theory as a "true anticipation" of inertia (Maier 1982, p. 77), asserted (in 1951) that Fabri resorted to Buridan's impetus in order to attack the new "mechanics of inertia" (*der Mechanik des Trägheitsprinzips*). She relied on apologetic letters written by Fabri to his fellow Jesuit Ignatius Gaston Pardies in 1673, in which he was eager to refute persistent accusations that his theory was similar to that of Descartes. Fabri did indeed – as Maier showed – distance himself in the first letter from Descartes' opinions concerning motion, claiming that he himself objected, e.g., to the two following Cartesian assertions: 1. "It is opposed to the laws of nature that an object once moved would come to rest." 2. "All movement by its own nature is straight".[3]

There can be no doubt that Maier's attitude strongly affected the view of subsequent writers. A. Boehm sharply distinguished (in 1965) between what he regarded as Fabri's Aristotelian conception of motion – according to which any kind of motion requires a continuing action of a mover – and Galileo's theory, which recognized (or led to the recognition) that motion can persist by itself without requiring a cause. Boehm contrasted Fabri, who adhered to the old concept of impetus, with Galileo – who (according to Boehm) managed to gradually abandon the theory of impetus and proceed "towards the theory of inertia" (Boehm 1965, pp. 346–347). Maurice Clavelin (1974) also followed in the footsteps of Maier, and paraphrasing her account remarked that "the impetus theory in the form Buridan had given it was so much of a piece with traditional mechanics that the seventeenth-century Jesuit Honoratius Fabri used it, in the name of the School, to refute Descartes' physics".[4] Stillman Drake similarly identified Fabri's theory of impetus with Jean Buridan's, and claimed that this concept is by no means close to the idea of inertia, insisting that impetus "is a kind of force (impressed force), and forces are not normally permanent in the modern sense of the word" whereas "Aristotle identified force

[3]Maier 1951, pp. 312–313. This is how Fabri describes some of Descartes' views, which he himself renounces (a passage quoted by Maier): "Docet... Deum omnium motuum solam causam esse; nihil reale et positivum in corpore moto reperiri, quod quiescenti non insit; legibus naturae adversari ut quiescat id quod semel movetur aut moveatur quod semel quiescit; omnem motum ex natura sua rectum esse" (Fabri 1674, p. 26; see also "Honoré Fabri: A Short Biography" above). Fabri's exact motives in formulating such an anxious attempt to distance himself from Descartes' philosophy are still not entirely clear – further research is required concerning this issue; it is highly probable though that it is connected to Descartes' 1663 condemnation, under Jesuit pressure and with the possible involvement of Fabri's himself (see Section 19.4 below).

[4]Clavelin 1974, p. 102, n. 116.

with violence, and held that nothing violent can long endure".[5] The big difference between the theories of Buridan and Fabri, especially in the context of CRM, will be fully discussed in this part. However, Drake also mentions a feature of Fabri's theory of horizontal projectiles which is indeed important and opposed to classical physics: according to the Jesuit, "contrary inclinations fight within the same body, and since the inclination downward due to heaviness is never diminished, it eventually wins out over an initial impressed impetus, however strong" (Drake 1974, p. 63). Drake's claim that according to Fabri natural motion downwards "eventually wins out" over the horizontal violent motion is misleading, because it implies a vertical fall at the end of the trajectory (it will be shown below that Fabri's solution includes no such vertical motion). However, Drake's assertion that in Fabri's analysis "contrary inclinations" always "fight" with each other is accurate and important: as will be shown below, this issue has no bearing on "pure" CRM – a principle fully adopted by Fabri – but it indeed implies a rejection of superposition between the components of projectile motion and therefore also a significant difference between Fabri's physical thinking and Galilean (as well as Classical) physics.

Paolo Galluzzi, generally endorsing the "formidable allegiance between the Copernican cosmology and the Galilean doctrine of motion" (Galluzzi 2001, p. 241) – and therefore unlikely to accept that a Jesuit supporter of Tycho's cosmological system could recommend an advanced idea like CRM – stated that "the notion of conservation of movement" was "not taken into account in Fabri's theory of motion".[6] Pietro Redondi presented Fabri as a staunch enemy of the notion of vacuum, allegedly owing to "the theological necessity of maintaining the hylomorphic perspective because of the theological necessity of safeguarding the scholastic interpretation of the Eucharistic dogma" (Redondi 1987, p. 295). It will be shown, later in this part, that (as Redondi remarks) Fabri indeed objected to the claim that Torricelli's "barometer experiment" had produced *de facto* an empty space; but nevertheless Fabri relied on "theological necessity" not to fight against the idea of void but rather to *endorse* its scientific validity and the possibility of motion through it. Ugo Baldini – referring not specifically to Fabri, but to all Jesuit philosophers of the period – sweepingly judged that "even after 1640 they constantly repeated the traditional analyses of motion: the majority accepted impetus, but they considered it as a self-consuming entity which cannot bring forth motion of indefinite or infinite duration, even in a vacuum in the total absence of external forces".[7] Alexandre Koyré

[5] Drake 1975, p. 33, n. 3.

[6] Galluzzi 2001, p. 267, n. 93.

[7] Baldini 2004, p. 106. In his article Baldini shows that the prominent Jesuit Gabriel Vazquez was "an important and even surprising exception" among the Jesuits (ibid., p. 107), adopting Buridan's view of the impetus as a non "self-consuming" property and yet rejecting Buridan's claim that motion without resistance (e.g. in void) is by definition impossible (ibid., p. 135). It seems worth checking for a possible influence of Vasquez on Fabri, as well as searching for some other contemporary Jesuits (even less explored by modern historians than Fabri and Vasquez) who might also be revealed as "exceptions".

deemed the notion of impetus inherently incompatible to the idea of CRM – his important argument (and the answer to it) will also be discussed in the next chapter.

In this Part I intend to show that the consensus around Fabri's attitude towards CRM, as well as the prevalent simplistic identification of Buridan's views with Fabri's, are incorrect and based on an incomplete or inaccurate reading of Fabri's texts. Maier, for example, read only Fabri's attempt, as an old Jesuit official, to reinterpret his own writings from the 1640s in a way which would distance himself from the philosophy of Descartes, following complaints received by his superiors.[8] She apparently did not consult these texts themselves – those of a young talented college professor, enthusiastic to integrate the exciting achievements of Descartes, Galileo, and others within the old structure – which had irritated his superiors in Lyon, and had probably led to his dismissal and relocation in Rome. My aim here is to show that although Fabri – unlike Descartes before him and Newton after him – did not proclaim CRM as a law of nature, his outright rejection of the Cartesian "inertial" statement ("it is opposed to the laws of nature that an object once moved would come to rest") in his apologetic letter to Pardies can hardly be considered as an exact (or even honest) account of his mechanics. Furthermore, Fabri's rejection of the second statement ("all movement by its own nature is straight") will be shown to be nothing more than a lie (if we consider only terrestrial physics). It will be shown that not only did Fabri take great pains to carefully construct his concept of impetus in order to allow for CRM; and not only did he explicitly describe what we would now call "inertial motions" within "thought experiments" which were possible by the guarantee of God; but he also explicitly and in some detail attacked Aristotle's rejection of motion in the void and conservation of motion, and relied heavily on arguments which he took (also explicitly) from none other than Galileo himself – allegedly the extreme opponent of Fabri and of the Jesuits in general.

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[8] See Blum 1999, p. 235, as well as Note 3 above.

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Chapter 13
The Conservation and Inexhaustibility of Impetus

Perhaps the most important objection to Fabri's "inertial" frame of mind was raised by David Lukens. It is worth addressing his objection in detail, since Lukens raises an issue that lies at the heart of Fabri's understanding regarding the impetus in general, and its conservation in particular. Referring to the issue of CRM (i.e. "inertia") in Fabri's thought, Lukens pronounces a decisive judgment: he claims that according to Fabri an impetus, i.e. an "impressed force", applied to an object – e.g., by the hand of a thrower – "cannot endure 'on its own' because whatever comes into being is not from itself and needs a cause to conserve it," and therefore inertia is not possible according to Fabri. Lukens concludes that "this is a key difference between impetus and inertia. The greatest weakness of Fabri's system lies in his refusal to grant (as Galileo did) conservation rules as simple facts confirmed by experience. Ax. 14 n.1 p. 11".[1]

As he claims, Lukens bases this assertion on "Ax. 14 n. 1", meaning the first of three axioms which according to Fabri are deducible from the main axiom, i.e. axiom number 14. Axiom 14 n. 1 says simply that "whatever exists, and does not exist from itself, exists, or is dependent, or conserved, by something else".[2] So, a being that does not exist in its own right (unlike God), and which can either exist or not – e.g. impetus – always "depends" on something else and has to be preserved by it in order to exist. At first glance it looks as though impetus really needs an *aliud* to preserve it, and therefore it is opposed to the idea of conservation of motion, but a closer look at Fabri's text will reveal that this *aliud* which he mentions turns out to be none other than God Himself, who is responsible for the conservation of impetus, as long as nothing impedes the moving body.

Let us look now at axiom 14 itself, which is the basis of Axiom 14 no. 1 quoted above:

[1] Lukens 1979, p. 140, n. 48.

[2] "Quidquid est, & non est a se, est, seu pendet, seu conservatur ab alio" (Fabri 1646, lib. 1, ax. 14, p. 11).

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> Axiom 14: Whatever is destroyed is not from itself. This axiom is geometric [i.e. certain[3]]; for whatever is from itself, exists necessarily; since it does not depend on the liberty or will of another; for since in the first instant in which something exists, it does not exist by itself, according to axiom 8; the same thing must be said about the second [instant], which [was said] on the first, which is clear. Obviously it does not exist necessarily in the first instant, because it is such that in that instant it is possible that it would not exist; but also in the second instant, it is such that it is possible that it would not exist; therefore it does not exist necessarily, therefore it depends on something else, which could cause it not to be.[4]

In other words, the factor which can cause something like impetus to exist also has the power to bring about its non-existence (*potest facere ut non sit*); this is only a hint concerning a non-physical, and omnipotent being that is responsible for the preservation of impetus, but this point will be made much clearer later on. Now let us examine all the related three axioms which according to Fabri follow from this one, and from which Lukens picked the first one to demonstrate Fabri's hostility to CRM:

> Recall now the following axioms, which are deduced from that single one.
>
> 1. Whatever exists, and does not exist from itself, exists, or is dependent, or conserved, by something else. For these are of course the same.
> 2. Whatever is destroyed, is destroyed according to an exigence of something, at least [the exigence] of the whole of nature, lest something exist in vain. This also follows from the hypotheses; for to be destroyed is the same as ceasing to be conserved; certainly, whoever ceases to conserve in instant A rather than B cannot do it unless something exacts (*exigit*)[5] it; that is, according to the laws of nature.
> 3. As long as nothing exacts the destruction of something, it is conserved. This follows from the former [axiom], i.e. as long as the reason – why it is and why it is conserved – is the same as before.[6]

So it is absolutely clear, from no. 2, that things which are destroyable actually require a reason for being destroyed; it is also clear, from no. 3, that as long as the previous reason responsible for a thing's existence and conservation continues to

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[3]Geometrical (also called "metaphysical") certitude is absolute, contrary to "physical" and "moral" (Chapter 1 above).

[4]"Quidquid destruitur non est a se. Hoc Axioma geometricum est; Quod enim est a se, necessario est; cum a libertate seu voluntate alterius non pendeat; cum enim primo instanti quo res est, non sit a se per Axiom. 8. de secundo idem dici debet, quod de primo, ut patet: quippe id eo primo instanti non est necessario, quia ita est illo instanti, ut possit non esse; sed etiam secundo instanti ita est ut possit non esse; igitur non est necessario, igitur pendet ab alio, quod potest facere ut non sit" (Fabri 1646, lib. 1, ax. 14, p. 11).

[5]The meaning and significance of the verb *exigere* is explained below.

[6]"Huc revoca Axiomata sequentia, quae ex hoc uno deducuntur. 1. Quidquid est, & non est a se, est, seu pendet, seu conservatur ab alio. Haec enim sunt idem, ut constat; 2. Quidquid destruitur, ad exigentiam alicuius destruitur, saltem totius naturae, ne aliquid sit frustra. Hoc etiam ex hypothesibus sequitur; cum enim destrui sit idem ac desinere conservari; certe qui desinit conservare instanti A potius quam instanti B, hoc facere non potest nisi aliquid hoc exigat; scilicet iuxta leges naturae; 3. Tamdiu aliquid conservatur, quamdiu nihil exigit eius destructionem. Hoc sequitur ex priori, id est quamdiu est eadem ratio, cur sit, & conservetur, quae erat ante" (Fabri 1646, lib. 1, ax. 14, p. 11).

exist, that thing will not be destroyed. It will soon be clear that at least when our "destroyable object" is impetus, this "reason" (*ratio*) – described in no. 3 as "the same as before" – must be the very Being designated by Descartes, in his *Principles of Philosophy*, as "the primary cause of motion" which, thanks to His immutability, "always preserves the same quantity of motion in the universe".[7]

In any case, axiom 14 – upon which Lukens based his claim that Fabri's physics is diametrically opposed to the notion of inertia – leads Fabri to formulate an important assertion, which contrary to Lukens's contention distances Fabri from scholastic physics and without a doubt betrays the great influence of Descartes. Theorem 89, which discusses the destruction of violent impetus, explicitly quotes axiom 14, and leads to a particularly interesting scholium:

> Theorem 89: regarding a violent impetus, which is gradually destroyed in projectiles, assuming the same circumstances of medium and resistance, less is destroyed in less time; and more in a greater [time]: because this destruction has a cause; for whatever is destroyed, is destroyed according to an exigence of something, according to axiom 14 no. 2. . .
>
> Scholium: you will notice also that without this theorem the destruction of violent impetus cannot be explained, as we shall see below.[8]

According to the Aristotelian tradition, every violent (i.e. unnatural) motion – being "against the nature" of an object – must necessarily be brief;[9] experience shows us, indeed, that these kinds of motion are almost always of a very short term. Because violent motion is brief, in traditional physics there is no need to explain the destruction of violent impetus; the fact that requires explanation is its (temporary) preservation, an observed phenomenon which cannot be denied. The crucial importance of the transition from the traditional question "why does a projectile (temporarily) persevere in its motion", which was asked by the traditional scholastics, to the query "why does the motion of a projectile cease" – which is expressed in the scholium of theorem 89 – was emphasized by none other than Descartes himself, in his *Le monde* (which had already been written by 1630 but was to be published for the first time only in 1662):

> Having supposed the preceding rule,[10] we are exempt from the trouble in which the *docti* find themselves when they want to give a reason why a stone continues to move for some time after having left the hand of the one who threw it: for one should rather ask why it does not continue to move forever? But the reason is easy to give. For who can deny that the air in which it moves opposes to it some resistance? (Koyré 1968, pp. 72–73)

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[7] *Principles of Philosophy,* part II, art. 36, in Descartes 1984–1985, vol. I, p. 240.

[8] "Impetus violenti, qui sensim destruitur in proiectis, positis iisdem circumstantiis medii, & resistentiae, minori tempore minus destruitur; plus vero majori: Quia haec destructio habet causam; nam quidquid destruitur, ad exigentiam alicuius destruitur, per Ax. 14. num. 2. . . Scholium: Observabis etiam sine hoc Theoremate non posse explicari destructionem impetus violenti, ut videbimus infra" (Fabri 1646, lib. 1, th. 89, p. 50).

[9] *On the Heavens* [Aristotle 1953], I, 269b5–269b8. See also end of Section 14.3 below.

[10] The law of "linear inertia", according to which (in Koyré's wording) "every particular part of matter continues always in the same state as long as the encounter of other parts of matter does not force it to change"; Koyré 1968, p. 72.

As will be shown below, in Chapter 16, Fabri's *answer* to the question "why does the motion of a projectile cease" – which involves the Aristotelian dictum that "nothing is in vain" – is completely non-classical; but it seems to me that the mere fact that Fabri raises this question is significant: Fabri insists that the destruction of violent impetus occurs only when something else positively "exacts" its destruction.[11] But then, how is violent impetus after all *conserved*? In theorem 144 Fabri states that impetus cannot be conserved by the original productive cause (*a causa primo productiva*), e.g. the thrower of a stone, since after the projectile has detached itself from it, it nevertheless keeps on moving;[12] therefore, he concludes, basing himself again on axiom 14:

> Theorem 145: hence impetus must be conserved by another cause; it is proved, because impetus does not exist by itself, because it is destroyed sometimes according to axiom 14. Therefore it is conserved by something else, according to axiom 14 no. 1, not by the original productive cause (by Theorem 144), therefore by another cause which is applied to it. . . Whatever that [reason] may be, we shall sometime prove it is the First Cause; now it is enough to say that there exists a certain applied cause, which conserves the impetus itself; indeed, from this conservation of things we shall sometime infer an argument, by which we will prove that God himself exists.[13]

In the third book, which deals with violent impetus, Fabri again attributes to God the role of conserving it, and even claims that the continuing motion of projectiles supplies an excellent means to prove the existence of the Almighty:

> Theorem 10: [Violent impetus] is conserved by a certain external applied reason; as is clear from what has been said above, it is not by air; therefore not by a body; therefore by another insensible cause;[14] therefore that [cause] must exist and must know the exigencies of all things and be capable of producing everything; since conservation is a repeated production; to be exact, to conserve through an action, by which a thing might exist in such a place at such a time; furthermore, that insensible and incorporeal reason, which exists everywhere and always is God; and do not think that the existence of the First Cause can be proved by an argument based more on the senses (*argumentum sensibilius*) – so to speak – than by that which is required by the motion of projectiles, whose motion persists even if the mobile itself is separated from the motive force.[15]

[11] The analysis of projectiles below explains Fabri's "destruction mechanism" of violent impetus, according to which gravity (innate impetus) is mainly (in fact, almost exclusively) responsible for this destruction.

[12] Fabri 1646, lib. 1, th. 144, pp. 67–68.

[13] "Hinc ab alia causa conservari necesse est impetum. Probatur, quia impetus non est a se, quia destruitur aliquando per Ax. 14. igitur conservatur ab alio per Ax. 14. n. 1. non a causa primo productiva per Th. 144. igitur ab alia, eaque applicata per Ax. 10. quaecumque tandem illa sit, aliquando causam primam esse demonstrabimus; nunc vero sufficiat dixisse dari aliquam causam revera applicatam, quae ipsum conservat impetum; immo ex hac ipsa rerum conservatione argumentum aliquando ducemus, quo Deum ipsum existere demonstrabimus" (Fabri 1646, lib. 1, th. 145, p. 68).

[14] *Causa insensibilis*, i.e. a cause which is not perceived by the senses.

[15] "Conservatur [impetus violentus] ab aliqua causa extrinseca applicata; ut patet ex dictis, non ab aere; igitur a nullo corpore; igitur ab alia causa insensibili; igitur illam esse oportet, & nosse rerum omnium exigentias, & posse cuncta producere; quippe conservatio est repetita productio; immo conservare per actionem, per quam sit res in tali loco, & tali tempore; illa porro causa insensibilis

In the next theorem Fabri clearly states that if there were no God, there would be no violent motion.[16] As for natural impetus, the corollary of theorem 11 of book II (dealing with free fall) states that it is the First Cause which is responsible for its conservation also.[17] In any case, theorem 147 from the first book expresses clearly – *pace* Lukens's contention – Fabri's conservation of impetus (i.e. also motion),[18] and yet again explicitly mentions axioms 14.2 and 14.3:

> Theorem 147: The impetus is conserved as long as nothing exacts (*exigit*) its destruction; because it is destroyed only according to the exigence (*exigentia*) of something, whatever it might be (to be discussed below), according to Ax. 14 no. 2; certainly it will not be destroyed, as long as there is nothing which exacts its destruction; therefore for this length of time it is conserved, according to Ax. 14 no. 3.[19]

As mentioned earlier, Alexandre Koyré criticized the concept of impetus – without specifically referring to Fabri – and addressed its (alleged) inherent incompatibility with the idea of conservation of motion. Here is Koyré's important explanation of the "anti-inertial" character of impetus:

> The theory of impetus. . . consists in taking motion to be the effect produced by a cause internal to the moving body. The conceptualization of this cause – the impetus – was very vague; it was thought of as similar to a form, or a quality, or a force. It is this force, impressed on the moving body by the action of the external mover – the impact – which, persisting in the moved body, explains the continuation of its motion. . . Impetus, being an efficient cause producing motion as its effect, diminishes as it produces it. It follows that all impetus becomes exhausted, i.e., becomes weaker by the very fact of the motion of the body which it is propelling. Therefore the motion slows down and every body set in motion has a tendency to return to rest. For there to be an acceleration the new *impetus*, the new impact or push or pull, must come into play while the earlier impetus still remains, i. e., while the body is still in motion.[20]

Furthermore, Koyré now claims that exactly this "anti-inertial" character of impetus was the reason why Galileo eventually abandoned the concept of impetus as a *cause* of motion, and used it only as an *effect* of motion:

> We must emphasize the fundamental importance of the fact that Galileo gave up the idea of impetus, the internal cause of the body's motion. He does, of course, keep the word, but with a completely different meaning: instead of being the *cause* of motion impetus becomes

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incorporea, quae ubique est, & semper, Deus est: Nec puta posse existentiam causae primae probari sensibiliori, ut sic loquar, argumento, quam eo, quod petitur ex motu projectorum, quorum motus durat etiamsi a potentia motrice mobile ipsum sit separatum" (Fabri 1646, lib. 3, th. 10, p. 137).

[16]". . . nullus esset Deus, nullus esset motus violentus" (Fabri 1646, lib. 3, th. 11, p. 137).

[17]Fabri 1646, lib. 2, th. 11, cor., p. 81; see also Chapter 8, Note 11 above.

[18]Fabri, as we shall soon see, is a staunch supporter of motion in a void, therefore – contrary to Buridan's view (to be also soon discussed) – Fabri's conservation of impetus unequivocally entails conservation of motion.

[19]"Tamdiu conservatur impetus, quamdiu nihil exigit eius destructionem; quia destruitur tantum ad exigentiam alicuius, quidquid tandem illud sit, de quo infra, per Ax. 14, n. 2. certe tamdiu non destruitur, quamdiu nihil est, quod exigat eius destructionem; igitur tamdiu conservatur per Ax. 14.num. 3" (Fabri 1646, lib. 1, th. 147, pp. 68–69).

[20]Koyré 1978, p. 71 (Koyré's emphasis).

> its effect. The idea of impetus as cause of motion purely and simply vanishes. This hybrid, confused and obscure idea has no equivalent in his thought. . . Already at Pisa, investigating the special, abstract cases of motion, i.e., the "simple" cases (circular motion "around the center"; horizontal motion, i.e., motion which is at the limit between the accelerated motion of fall and decelerated upwards motion), Galileo had learned that, in such cases, contrary to the basic intentions of impetus theory, motion seemed to be able to last for ever. . . He saw clearly that impetus, if it is defined as the cause of motion, must be used up as it generates the motion.[21]

According to Koyré, therefore, conceptualizing impetus as a cause – that is, an efficient cause – of motion, renders motion non-inertial *ipso facto*, for impetus "must be used up as it generates the motion". As we have seen in Section 5.3, Jean Buridan – although not having explicitly defined impetus as an *efficient* cause of motion – nevertheless claimed, according to standard Aristotelian thinking, that "every motion arises from a motor being present and existing simultaneously with that which is moved". It seems then that Buridan – although claiming for his part that impetus is indeed "permanent", i.e. is conserved if not impeded – does not have an adequate answer to the claim raised by Koyré.

As already hinted at, however, Fabri has an excellent answer to Koyré's argument. In the first part I described Fabri's division of motion to two "types" (in theorem 3 of the *De impetu*): the first one, associated with the first stage of projectile motion, in which the motive force impresses impetus in the projectile and the second one, caused by the impressed impetus. As the reader might recall (from Section 4.3), the first type of motion involves an "exhaustion" of the motive force while the second does not. In the following theorems Fabri explicitly connects this issue with the kind of causality involved. In theorem 5 he states that the activity of exacting, or compelling (*exigere*) – the verb he has chosen for specifying the way impetus causes motion (see beginning of Chapter 4) – does not imply the exhaustion of the (formal) cause, while the action of producing (*producere*) is indeed accompanied by the exhaustion of its (efficient) cause:

> A motive force of a projectile really acts, also because it is exhausted;[22] therefore it produces something, not directly motion, which cannot be properly produced, according to theorem 2.[23] Furthermore, motion of the second kind[24] has only an exacting immediate cause, but a motive force does not exact; because *first of all it would not be exhausted by exacting*; secondly, because a stone moves even after being separated from the [throwing] hand, but clearly not by the exigence of the motive force; because immediately after the separation that force can be destroyed, even though the stone moves for a long time afterwards; but a thing which does not exist, does not exact anything.[25]

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[21] Koyré 1978, p. 75 (Koyré's emphasis).

[22] My translation of "cum etiam defatigetur" follows from what Fabri says in theorem 6 (see Note 26 below): "potentia motrix est activa, quia defatigatur".

[23] "Motus non potest dici proprie productus immediate, vel effectus immediatus causae efficientis" (Fabri 1646, lib. 1, th. 2, p. 12).

[24] The motion by which a projectile proceeds after being separated from the projecting agent.

[25] ". . .potentia motrix proiicientis vere agit, cum etiam defatigetur; igitur aliquid producit, non motum immediate, qui produci non potest proprie per Th. 2. Adde quod motus secundi generis

In theorem 6, which tries to prove the existence of impetus, Fabri emphasizes yet more clearly the important connection between "acting", "producing" and "being exhausted": "The motive force is active, because it is exhausted; who will deny that? Therefore it produces something; not motion, which is not produced according to theorem 2. Therefore [the motive force produces] something else; [which] I call 'impetus' ".[26]

So Fabri rules out (in theorem 5) the possibility of explaining the projectile's prolonged motion by the action of the motive force not only in light of the obvious argument, that the destruction of the motive force would not entail the cessation of that motion; more importantly for us, he also insists that *if the motive force exacted motion*, *it would not be exhausted*. The inevitable conclusion is that impetus is indeed not exhausted while exacting motion, and this is why Fabri can safely declare – in theorem 147 quoted above – that impetus is conserved as long as nothing destroys it. Contrary then to the impetus which Koyré described, and which was indeed used by Galileo in his *De motu*, Fabri's impetus is not "used up" by the motion for which it is responsible.

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habet tantum causam immediatam exigentem, sed potentia motrix non exigit; quia primo non defatigaretur exigendo; secundo quia lapis separatus a manu etiam movetur, sed non ad exigentiam potentiae motricis, ut patet; quia statim post separationem potest illa potentia destrui, licet lapis longo post tempore moveatur; sed quod non est, nihil exigit" (Fabri 1646, lib. 1, th. 5, p. 14; my emphasis).

[26] "...potentia motrix est activa, quia defatigatur, quis hoc neget? igitur aliquid producit; non motum, qui proprie non producitur per Th. 2. igitur aliquid aliud; voco impetum" (Fabri 1646, lib. 1, th. 6, p. 15).

Chapter 14
Motion in the Void

I have just claimed that Buridan (unlike Fabri) would probably have found Koyré's argument against the self-conserving character of the impetus difficult to deal with. However, Buridan *did* regard impetus as a permanent entity, and even claimed that "the impetus would last indefinitely (*in infinitum*) if it were not diminished by a contrary resistance or by an inclination to a contrary motion" (Clagett 1959, p. 525). Buridan indeed claimed that the impetus which had been (possibly) imparted to the heavenly bodies in the moment of creation has been preserved since that time, moving them along their circular trajectories; he and also observed that a smith's mill "continues to move for a long time" after the moving cause has been removed (ibid., pp. 534, 536), but he nevertheless stopped short of arriving at linear (and sublunary) conservation of motion. Clagett explains:

> One might suppose from his arguments that, were there no resistance, not only would the impetus last indefinitely (as he states) but also that the movement maintained by the impetus would be both finite[1] and uniform. However, such a conclusion would be difficult to fit in the Aristotelian framework, which Buridan generally accepted. (Clagett 1959, p. 539)

Aristotle indeed – while denying the ability of motion in the void, i.e. motion devoid of any resistance[2] – has set up a tough obstacle to the notion of conservation of linear motion. Most historians – with Duhem as an obvious exception[3] – agree with Clagett concerning Buridan's commitment to Aristotle on this issue, and stress the strength of the standard scholastic tradition which opposed CRM. Maurice Clavelin, for example, discussing the law of preservation of motion observes that "the ideal state presumed by the law (the absence of external resistance to motion) would be impossible (not solely unreal) in the entire tradition of scholastic physics,

[1] It will soon be shown that according to Aristotle, the total absence of resistance does not imply finite motion; rather, it entails impossible "instantaneous" motion.

[2] Aristotle explains, for example, that without a medium, projectile motion would be utterly impossible (see Section 14.3 below).

[3] See, e.g., Maier 1982, p. 77.

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in which motion would always require the existence of resistance".[4] Maier emphasizes that according to scholastic tradition, motion – as a successive entity – cannot conserve itself, despite the permanence of impetus.[5] Edward Grant describes Buridan's strong objection (in his *Questions on the Physics*) to the possibility of motion in a vacuum, and even speculates that "it may have been an implicit desire to avoid the inertial consequence of his own impetus theory which drove Jean Buridan to oppose the concept of motion in the void".[6] The important point, in any case, is that Buridan's view – loyal to this scholastic tradition – simply meant that the conservation of impetus did not entail conservation of motion.

Fabri, of course, lives in a period three centuries removed from his medieval predecessor, an era much less under the yoke of Aristotle. Giovanni Battista Benedetti came quite close to CRM in 1585, by claiming in his *Diversarum speculationum mathematicarum et physicarum liber* that "any portion of corporeal matter which moves by itself when an impetus has been impressed on it by any external motive force has a natural tendency to move on a rectilinear, not a curved, path. And so, if some portion of the circumference were separated off from the wheel in question, no doubt the separated part would move through the air in a straight line for some length of time".[7] Isaac Beeckman (1613) and Pierre Gassendi (1642) asserted that whatever is set in motion remains in motion forever, and considered conservation of motion as a universal principle, applying to (unimpeded) rectilinear and circular motions alike.[8] Galileo, accepting as natural and perpetual only the constant circular motions of the heavenly bodies, never explicitly formulated CRM, though there can be no doubt he intuited it to some degree; his disciples, Cavalieri (1632) and Torricelli (1644), clearly accepted this principle, without presenting it as a key rule.[9]

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[4]This is Baldini's paraphrase of Clavelin's view (Baldini 2004, p. 135). Baldini emphasizes (ibid., p. 101, n. 4) that "even the 'continuist' historians," among whom he includes Marshall Clagett, Edward Grant, and William A. Wallace, "had to qualify and delimit Duhem's theories" (which as is well known identified the mere conservation of impetus with inertia), "while a larger number of scholars upheld and in some respects even radicalized Koyré's theories, although in very different ways (Anneliese Maier, Stilman Drake, Maurice Clavelin, Winifred L. Wisan)".

[5]Maier 1982, p. 160. Fabri, loyal to his general ambiguity regarding the ontology of motion, asserts that it is "potentially successive essentially" (*successivus essentialiter potentia*), but "nevertheless not necessarily actually" (*non tamen actu necessario*); Fabri 1648, lib. 12, prop. 24, p. 498.

[6]Grant 1964, p. 275. See also Grant 1981, pp. 45–46 and p. 292, notes 90–92. There are passages in Buridan's text which have been interpreted by Pierre Duhem as indicating Buridan's change of mind, but Grant convincingly rejects such an interpretation (Grant 1964, pp. 279–280; see also Section 14.3, especially Note 70 below). Even if we do accept that Buridan might have been "wavering" on the possibility of motion in the void, his position is in any case a far cry from Fabri's decisive stand, to be exposed in the following pages.

[7]Drake and Drabkin 1969, p. 186. Drake remarks that "were it not for the phrase 'for some length of time'. . . the inertial concept [i.e. CRM] would be unequivocally given" (ibid.).

[8]For Beeckman's view, see Koyré 1978, pp. 79, 116–117. For Gassendi's: ibid., p. 246; Palmerino 2004, pp. 151–152; Pav 1966, pp. 27–29.

[9]On the supremacy of circular over linear motion in Galileo's thought see Galilei 1953, pp. 36–38 and 1989, p. 233. On the debate among researchers concerning Galileo and CRM see Palmerino 2004, p. 162, n. 32; Wolff 1987, pp. 237–238; Finocchiaro 2003, pp. 218–219; Damerow et al.

Descartes was the first to formulate explicitly and unequivocally (and as a basic law of nature) the principle of CRM around 1630 in his *Le monde*, which was published only after his death, and also in his *Principia philosophiae* (1644) – published two years before Fabri's *Tractatus physicus de motu locali* and four years before Fabri's *Metaphysica demonstrativa*.

14.1 *De loco* and the Defense of Void

Since Fabri was so agile in following in Descartes' footsteps concerning the important issue of CRM, it is somewhat ironic that the Jesuit chose to devise his severe rift with Aristotle's physics (which as will soon be shown, would directly lead Fabri to adopt CRM) around the subject which both Aristotle and Descartes detested: the void. In contrast to Aristotle, Buridan, the entire scholastic tradition, and even Descartes and Galileo, Fabri saw no problem whatsoever in imagining an object moving forever in a vacuum along a straight line with constant velocity.[10] But before describing Fabri's decisive opinion concerning rectilinear motion in the void, it is worth presenting Fabri's (no less decisive) view regarding vacuum per se, which is outlined in book 8 (*De loco*) of his *Metaphysica demonstrativa*.

The beginning of *De loco* is dedicated to proving that beyond "Aristotelian place" (*locus*) – "the innermost motionless boundary of what contains"[11] – there must exist a more general type of space, *ubicatio*, which allows for existing in a void, where of course there is nothing which could "contain". We have encountered (in Section 9.1) Fabri's notion of *duratio* – the "principle of existing in time", an autonomous concept of time which does not depend on motion, an intrinsic *ratio formalis* "by which a certain thing is said to be now, before, after (*nunc*, *ante*, *post*)". Likewise, *ubicatio* is defined by him as a "principle of existing in place", a *ratio formalis* by which "something is in that place, in another place, in any place (*ibi*, *alibi*, *alicubi*)".[12] Later Fabri explains that *ubicatio* is a mode, and thus cannot exist – not even by a miracle – separated from the subject it modifies.[13]

The first proposition of *De loco* explains why "Aristotelian place" is not enough:

2004, p. 264 (especially note 182). On Cavalieri and Torricelli see Koyré 1978, pp. 237–243 and Damerow et al. 2004, pp. 284–285.

[10] Grant, among others, pointed out the paradoxical fact that Descartes, who denied the possibility of empty space, "enunciated the principle of inertia when the foundations of his new physics made the realization of that principle utterly impossible" (Grant 1964, p. 291, n. 87).

[11] *Physics* [Aristotle 1930], 4, 4, 212a20.

[12] "Ubicatio est ratio existendi in loco. Non dico esse aliquid distinctum ab eo, quod in loco est, vel ab ipso loco. . . ita prorsus concretum hoc locatum (ut ita dicam) ubicatum, esse in loco, esse hic, vel illic, esse loci, habet rationem formalem huius esse localis, quam voco ubicationem, qua scilicet res aliqua ibi, alibi, alicubi est" (Fabri 1648, lib. 8, def. 1, p. 313).

[13] "Septimo, non potest ubicatio existere separata, quia est modus" (Fabri 1648, lib. 8, prop. 14, p. 333); on modes see Sections 4.1 and 4.2 above.

Something can exist, and not be in an Aristotelian Place. It is proved [because]:

1. God does not exist in an Aristotelian place, which is clear, indeed nor does an angel, speaking properly;
2. God can destroy all the air in this room – everything else having been excluded, so that it would not be substituted into the place of the former [the air] – and retaining the walls themselves, so that they are not joined; and yet I exist in the middle of the room, and I am not in an Aristotelian place, because there is not any surface of a body surrounding me, therefore I would exist, and not be in an Aristotelian place.[14]

Furthermore, Fabri knows that someone might deny the viability of the antecedent of this argument (i.e. that God can "eliminate" all the air from the room), and argue that it is not possible to create a void, even by a miracle.[15] This is Fabri's answer:

Does that air which occupies the whole capacity of this room depend on God? Who would deny this, apart from an atheist, with whom I can have no business at the moment? Therefore it can be destroyed by God.[16]

Fabri – having bluntly branded those who deny the scientific legitimacy of vacuum as "atheists" – continues to defend the possibility of the existence of the void (guaranteed by God, of course), and he has an answer to a typical Cartesian objection to the very idea of void (without mentioning Descartes by name):

You will say that this vacuity cannot be conceived without extension, and extension [cannot be conceived] without a body; [But] it is no wonder that the consequence is false, because it follows from a false assumption; for, firstly, I do not conceive a vacuum with a positive extension, but only according to the mode of a certain capacity, which an extended body could occupy. Secondly, I also deny that the essence of extension is simply conceived as a body; since it is also compatible to an Angel, and indeed there is nothing more extended than God, whose extension is infinite.[17]

[14] "Potest aliquid existere, & non esse in loco Aristotelico: Probatur primo Deus non est in loco Aristotelico, ut constat; imo nec Angelus, proprie loquendo; Secundo Deus potest destruere quidquid aeris est in hoc cubiculo, excluso dumtaxat omni alio, ne in locum prioris substituatur, retentisque ipsis parietibus, ne scilicet conuingantur; ego tamen existo in medio cubiculo, & non sum in loco Aristotelico, quia nulla est corporis ambientis me superficies, igitur existerem, & non essem in loco Arsitotelico" (Fabri 1648, lib. 8, prop. 1, p. 315).

[15] "Antecedens a quibusdam recentioribus negatur, dicunt enim etiam per miraculum non posse dari vacuum" (Fabri 1648, lib. 8, prop. 1, p. 315).

[16] ". . . nunquid aer iste, qui occupat totam huius cubicili capacitatem, dependet a Deo; quis hoc neget, nisi Atheus, cum quo mihi res modo esse non potest; igitur a Deo destrui potest" (Fabri 1648, lib. 8, prop. 1, pp. 315–316).

[17] "Dices non posse concipi illam vacuitatem sine extensione, neque hanc, sine corpore; quid mirum, si consequens falsum sit, quod ex antecedente falso sequitur; nam primo non concipio vacuum cum extensione positiva, sed tantum per modum capacitatis cuiusdam, quae corpus extensum capere possit; Secundo nego etiam extensionem simpliciter esse conceptum essentialem corporis, quippe illa etiam competit Angelo, imo nihil magis extensum quam Deus, cuius extensio est infinita" (Fabri 1648, lib. 8, prop. 1, p. 316).

Thus by conceiving a vacuum as a "capacity, which an extended body could occupy", Fabri disconnected the concept "body" from "extension", allowing – *pace* both Aristotle and Descartes – the possible existence of an extension totally devoid of body (i.e. matter).[18] Fabri now discusses the issue of motion in a void, and formulates again a rhetorical question, to which a negative response would entail a denial of God's omnipotence:

> Finally, is God at least able to move me in that vacuum? I say "God at least", because even a stone can be moved in that little vacuum naturally, as has been said in the *Tractatus physicus*. And we shall say elsewhere, that it therefore acquires and relinquishes a place; because motion cannot be perceived without a place left and a place acquired, by Axiom 8. Therefore in that vacuum I would yet exist; but there would not be any surface of a surrounding body, therefore I would not exist in an Aristotelian place, by propositions 1 & 2; therefore I would have another place, whatever that will finally be, so except for an Aristotelian place, there exists another.[19]

So a body in a vacuum can move – i.e. acquire and relinquish places – notwithstanding the absence of a surrounding medium, and thus we must employ a broader definition of place than the one Aristotle supplies. Fabri's arguments, relying on God's potency to invalidate Aristotle's opinions, are of course highly reminiscent of the 1277 condemnation by the Bishop of Paris, Stephen Tempier, directed against claims which seemed to jeopardize God's omnipotence.[20] Merely defending the notion of void against Aristotle, or allowing motion in it, have of course a rich scholastic background. Furthermore, it is not hard to identify the influence of Suárez on Fabri's concept of *ubicatio*, including the attempt to disconnect it from Aristotle's concept of place and thus allow for motion through the void. In his *Disputatio LI*, entitled *De ubi*, the Spanish Jesuit regards *ubi* as "a certain mode, real and intrinsic to the thing which is said to be in any place", by which this thing has the property of being "here or there" (*hic vel illic*). Suárez emphasizes that the mode *ubi* "does not depend on a circumscribing body, nor on anything else extrinsic, but only materially on the body which is in any place". Later Suárez insists that God can move a body through a vacuum, and it would thus acquire "a mode of presence" (i.e. *ubi*) despite the absence of a surrounding surface.[21]

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[18] On Fabri's view as a reaction to Descartes' rejection of vacuum, see also Part IV, Section 19.1 below.

[19] "Denique nunquid Deus me saltem movere posset in illo vacuo; dico Deum saltem, nam etiam lapis in illo modico vacuo moveri posset naturaliter, ut dictum est tom. 2. Dicemusque alias, igitur acquirere locum, & relinquere; quia non potest concipi motus sine loco relicto, & acquisito per ax. 8. igitur in illo vacuo essem adhuc in loco; sed non esset ulla superficies corporis ambientis, igitur non essem in loco Aristotelico, per p, 1 & 2. igitur haberem alium locum, quidquid tandem sit, igitur praeter locum Aristotelicum, alius est" (Fabri 1648, lib. 8, prop. 2, p. 316).

[20] See, e.g., Lindberg 1992, pp. 236–240.

[21] *Disputationes metaphysicae*, disp. 51, sect. 1, n. 13 in Suárez 1856–1878: "Est ergo quarta sententia, quae affirmat, id, quod est formale in praedicamento Ubi, esse quemdam modum realem et intrinsecum illi rei, quae alicubi esse dicitur, a quo habet talis res, quod sit hic vel illic. Qui modus per se non pendet a corpore circumscribente, neque ab aliquo alio extrinseco, sed solum materialiter a corpore, quod alicubi est"; ibid., n. 21: "Denique posset Deus movere localiter corpus per

However, Fabri will be shown to have gone much further than any of his scholastic (or Neoscholastic) predecessors, being heavily (and explicitly) influenced by the pioneer of the New Science, the self proclaimed staunch enemy of Aristotelian philosophy – Galileo. Fabri's interesting analysis concerning motion in the void, which will soon be outlined, is to be found in an appendix of *Metaphysica demonstrativa*, succinctly and appropriately entitled *De vacuo*.

14.2 *De vacuo* and the "Inertial Thought Experiment"

Fabri's main purpose in *De vacuo* is not very "progressive": it is intended to refute Evangelista Torricelli's contention that his famous "barometer experiment" (performed in 1643) indeed created vacuum. This experiment was thus described by the English contemporary Sir Matthew Hale:

> A glass tube of three foot or more long, closed at one end, and then filled with mercury or quicksilver, and then the open end stopped with the finger, and inverted into a vessel of restagnant ["overflowing"] mercury; and when the end is sufficiently immersed, then the finger nimbly removed, so that no air get in, the mercury will subside in the tube to the height of 29 ins. and half an inch, or near thereabouts, but infallibly between 27 and 30 ins, leaving the residue of the upper end of the tube emptied of the Mercury (Cromartie 1995, p. 209).

A major controversy developed, as is well known, about the true nature of what was contained in that "residue of the upper end of the tube emptied of the Mercury". The "moderns", supporting Torricelli, claimed that what was produced there was genuine vacuum, while the Aristotelians of course counter-claimed that this idea was ridiculous. Fabri thought that although void was not impossible, nevertheless Torricelli's experiment could not have produced a vacuum, and held (along with the English Jesuit, Francis Line) the opinion that the upper, seemingly empty part of the tube actually contained vapor extracted from the mercury itself.[22] Fabri's opinion is considered today "conservative" and "antimodern", although it is perhaps worth mentioning that a modern physics textbook, which refers exactly to that upper part of the tube, explains that "the space above the mercury contains only mercury vapor, whose pressure is so small at ordinary temperature that it can be neglected" (Halliday et al. 1993, p. 449).

But as Pietro Redondi correctly remarked, Fabri's explanation reveals that he did not understand the role of atmospheric pressure.[23] However, one of Redondi's claims concerning Fabri's opinions in this context is a total distortion of the Jesuit's

vacuum, ut nunc suppono, quia nulla potest ostendi implicatio contradictionis; ergo tunc acquireret corpus modum praesentiae sine superficie circumscribente". See also Grant 1976, pp. 78–79.

[22] Cromartie 1995, p. 214; Fabri 1648, app. 1, pp. 570–580.

[23] Redondi 1987, p. 294; Fabri's explanation of Toricelli's experiment is still in terms of *horror vacui*.

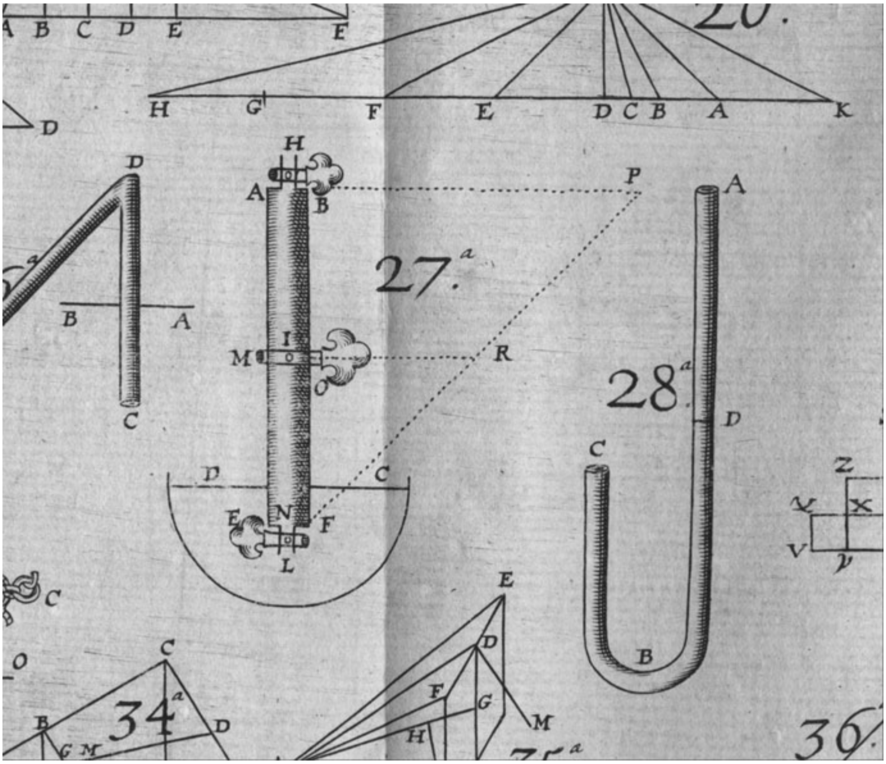

Fig. 14.1 Fabri's depiction of Torricelli's experiment (figures 27 and 28; Fabri 1648, p. 658)

position and it deserves a reservation, or correction – even though it is a digression from our main subject – because it represents typical prejudice against figures like Fabri. Redondi asserted (in a footnote) that "it should be remembered that the requests on the part of scientific Jesuit groups for greater autonomy in research were inspired by a desire for greater apologetic effectiveness vis-à-vis the outside world and against the 'perverse minds of Heretics'. H. Fabri, *Metaphysica demonstrativa*, Lugduni 1648, p. 579".[24] The reference Redondi supplies is correct, but this is an extreme misrepresentation of Fabri's scientific attitude. Fabri has just explained why he was convinced that a void could not have been created above the mercury, and he subsequently rejects two kinds of philosophers who "are hostile to physics" (*vero hominum*, *genera duo sint*, *infestorum rei physicae*): on the one hand, those who avoid philosophy and rely only on experiments, and thereby deduce "*absurda*", according to the saying "an experiment in the hand of the ignorant is a

[24]Redondi 1987, p. 289, n. 45.

sword in the right hand of a madman" (*experimentum in manu inscii*, *esse gladium in dextera furiosi*);[25] and on the other hand, those who "reject all experiments, and exclude them from philosophy, as though they were completely unworthy by the schools" (*qui cuncta experimenta reiiciunt*, *& e philisiophia proscribunt*, *quasi scholis penitus indigna sint*). Now Fabri indeed says that "certainly, philosophy will be pleased by (so called) subtle arguments, in order to convince the perverse minds of Heretics"; however, he immediately adds that "whoever feels this way, is not a physicist; certainly the only duty of physics is to reduce natural and sensible effects, i.e. experiments, to their physical causes".[26]

From Redondi's remark we could get the impression that the main purpose of the physics of Fabri (and his Jesuit colleagues) was to "convince heretics". However, it is clear that although Fabri is aware of this possibility of persuading heretics (and naturally does not object to it), he emphasizes that this is *not* the duty of the physicist; Fabri concludes this paragraph (and also the whole appendix *De vacuo*) by reiterating his main point here, that "experiments are very useful and extremely necessary to physics, as long as a knowledgeable and wise person conducts them".[27]

Back to our main subject. Despite the "conservative" character of what seems to be the main purpose of *De vacuo*, this appendix does contain important ideas. First of all, Fabri denies the possibility of void existing (or artificially created) *inside* the universe, but asserts that the whole universe itself is immersed in an infinite void.[28] But even more interesting is Fabri's detailed discussion concerning motion in the void, appearing in proposition 35 of *De vacuo*.

[25]Fabri's metaphor brings to mind Socrates' (rhetorical) question, whether it is appropriate to return a weapon to a person who lent it when he was sane but is now "out of his mind" (*Republic*, 1, 331c, in Plato 1997).

[26]"... nempe res Philosophica subtilioribus (inquiunt) gaudet argumentis, ut protervas Haereticorum mentes convincat: quisquis ita sentit, physicus non est; nempe physici tantum muneris est, effectus sesibiles & naturales, hoc est experimenta, ad suas causas Physicas reducere" (Fabri 1648, app. 1, prop. 36, pp. 579–580).

[27]"... itaque optima sunt experimenta, & rei Physicae maxime necessaria, dum illis vir sapiens & sciens utatur" (Fabri 1648, app. 1, prop. 36, p. 580).

[28]"...itaque obiicitur: Primo, orbem hunc universum esse in vacuo, cum revera a vacuo, id est a spatiis imaginariis ambiatur; sed quaestio in eo sensu minime procedit, nam quis hoc negat; negamus tamen infra hunc rerum corporearum ambitum, aliquod vacuum esse" (Fabri 1648, app. 1, p. 569). Despite associating the infinite void with "imaginary space", which Fabri regards (in "De loco", the eighth book of Fabri 1648) as an *ens rationis*, rather than a real entity (Fabri 1648, lib. 8, prop. 16, p. 336), there can be no doubt that he indeed believed in an extracosmic void, for in the same page he asserts: "... extra fines mundi, est mera vacuitas; id est negatio rei creaturae". Furthermore, Fabri can easily visualize a stone being brought (by an angle) into this vacuum which surrounds the universe, and tries to predict what would happen to it ("Quaeres, si lapis ab Angelo deferretur, extra huius mundi confinia, scilicet in spatia illa imaginaria, utrum ubi quiesceret; Respondeo, negando, sed deorsum tenderet, vel ad centrum terrae, vel in alium totalem globum se reciperet, qui propius occurreret"; Fabri 1648, app. 1, prop. 36, p. 569). The possibility of the existence of vacuum outside the universe – to be identified with God's immensity – was (hypothetically) raised already by Thomas Bradwardine and Nicole Oresme; Grant 1969, pp. 48–49.

Proposition 35 starts in a peculiar manner (from a 21st century perspective), but soon we can easily discern in it a new tone, quite alien to medieval (let alone Aristotle's) dynamics:

> In a total void, an angel could move, indeed an animal; because nothing would impede a power of a motive force, determined along such a line: hence were a man to be conserved by God in that total void, he could move in any direction, almost in the way in which fish swim in water; hence since there would not be any resisting gravitation, nor any medium, he would henceforth conserve the impetus impressed on him... Hence the medium would be most suitable to motion, obviously since it would in no way resist the mobile; hence motion could be impressed on another mobile, e.g. on a stone; its motion, once impressed, would henceforth always endure, [because] there would be nothing by which it could be destroyed: hence a stone, after being thrown, would move *in infinitum* with constant motion.[29]

Fabri's claim that the void would be "*aptissimum ad motum*" is of great importance, as we can infer from the arguments of Clagett and Clavelin cited in the beginning of this chapter, to which we can add Maier's remark:

> in the absence of all resistance... according to scholastic theory, no motion in the strict sense would occur. Instead there would be a *mutatio*, that is, an instantaneous change of position, rather than a successive process that takes place over time. (Maier 1982, pp. 95–96)

The scholastic tradition indeed generally regarded change of substance (*generatio* or *corruptio*) as an instantaneous *mutatio*, to be differentiated from *motus* (*κίνησίς*), i.e. change of place, quality, or quantity.[30] Fabri, in his account, does not seem to distinguish between *motus* and *mutatio*.[31] But the important point, of course, is Fabri's rejection of the contention that motion in the void implies "an instantaneous change of position", and the formulation of CRM: A stone in a void "once impressed... would move infinitely with constant motion" and (as is implied by the beginning of the paragraph) along a straight line.[32]

Now Fabri describes a "thought experiment" in which God destroys everything except the (moving) stone, and explains the nature of the resulting inertial motion:

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[29]"In vacuo totali, posset Angelus moveri, imo animal; quia nihil impediret vim potentiae motricis, ad talem lineam determinatae: hinc si homo in illo totali vacuo, a Deo conservatur, quoquo versum moveri posset, eo fere modo, quo pisces in aqua natant; hinc cum nulla esset gravitatio resistens, nec ullum medium, impetum sibi impressum deinde conservaret... Hinc esset medium ad motum aptissimum, quippe quod nullo modo mobili resisteret; hinc posset imprimi motus alteri mobili, v.g. lapidi; qui semel impressus, deinde semper duraret, nihil esset a quo destrui posset: hinc moveretur in infinitum motu aequabili lapis, post iactum" (Fabri 1648, app. 1, prop. 35, p. 563).

[30]See also Des Chene 1996, p. 25.

[31]See Fabri's second theorem of *De impetu* (quoted in Section 4.3, Note 29).

[32]The motive force, "determined along a line," naturally impresses linear motion on the moving body. The linear character of Fabri's conception of impetus and motion (and its conservation), as well as his Cartesian concept of *determinatio*, are discussed below in Chapter 15.

> Indeed if God were to destroy everything except the stone, then this stone would immediately move because of the innate impetus which is in it (*propter impetum innatum*, *qui ipsi inest*),[33] namely with constant motion; for natural acceleration belongs only to heavy things which go towards the center; indeed that innate impetus would be in vain;[34] therefore it would have to be destroyed;[35] therefore this[36] would only occur on the assumption that the innate impetus is not destroyed; yet if, while the stone moves upwards with decelerated violent motion, everything else were to be destroyed, it would then never stop, but would move with constant motion, namely retaining the same level of velocity which it had at that very instant in which the rest of the world was destroyed.[37]

What does Fabri mean by claiming that the stone, following the destruction of the rest of the universe, will move "because of the innate impetus which is in it (*qui ipsi inest*)"? Contrary to what might be understood, Fabri does not mean that a stone *at rest* in the moment of the universe's destruction would spontaneously begin to move. This interpretation is ruled out by the previous proposition (34), which claims that "if there were a total vacuum, a stone placed in it would not move through a natural motion from the inside; for whither would it move? Why would one direction be preferred over another? There would be no center of the world to which it could tend".[38] Hence in proposition 35 the stone is not moved by any "natural" internal motion: as Fabri explains again (in the passage just quoted), the innate impetus involved in such motion would be in vain and therefore destroyed. So how would a stone already moving before the universe's destruction continue to move afterwards? Fabri's example – the upward moving stone – supplies the answer (apparently the meaning of the "*innate impetus qui ipsi inest*", i.e. that which is not destroyed): "retaining the same level of velocity which it had at that very instant in which the rest of the world was destroyed."[39] Interestingly, Fabri does not

[33]Fabri usually associates "innate impetus" with gravity, i.e. the inclination of bodies towards the center of the earth (as opposed to violent impetus, which is impressed from outside and causes violent motion). However, in this "thought experiment" – as will soon be apparent – this "innate impetus" has a double meaning.

[34]Because a center would no longer exist.

[35]According to Fabri, whatever is "in vain" cannot continue to exist.

[36]i.e. the uniform motion.

[37]"Imo si modo Deus cuncta destrueret, praeter lapidem, hic statim lapis moveretur, propter impetum innatum, qui ipsi inest, scilicet motu aequabili; nam naturalis acceleratio, est tantum gravium, quae ad centrum eunt; imo frustra esset impetus ille innatus; igitur destrui deberet; unde hoc tantum accideret, ex suppositione impetus innati non destructi; si tamen dum lapis movetur sursum, motu violento retardato, caetera omnia destruerentur, nunquam deinde sisteret, sed moveretur motu aequabili, retento scilicet eo gradu velocitatis, quem habebat eo instanti, quo reliquum orbis destructum est" (Fabri 1648, app. 1, prop. 35, pp. 563–564).

[38]"Si esset vacuum totale, in eo lapis collocatus, non moveretur, motu naturali ab intrinseco; quo enim moveretur; cur potius in unam partem, quam in aliam; nullum centrum orbis esset, ut eo tenderet; haec ita certa sunt, ut a nemine in dubium revocari possint" (Fabri 1648, app. 1, prop. 34, p. 563).

[39]This point is somewhat clearer in the *Physica*, in which Fabri repeats this discussion of a stone existing, or moving, in vacuum. Fabri again explains that "innate impetus" in this case would be in vain (and thus destroyed), but "nevertheless if it [i.e. impetus] would be determined from outside, it would bring forth its effect (si tamen ab extrinseco determinaretur, effectum suum praestaret)",

claim here that the impetus is conserved (though this would be his justification for the resulting uniform motion), but directly refers to the inevitable conservation of uniform velocity, which is expressed by the stone simply "retaining the same level of velocity". It is as if once the concept of impetus has been used by him to prove CRM, Fabri does not need it anymore, for it is hard to avoid the impression that Fabri has in mind here the principle of sufficient reason: being devoid of any obstacle, the empty space in which the stone moves provides no reason why it should not indeed retain its original velocity.[40]

No less interesting than Fabri's "inertial statements" is his presentation of possible objections to motion in the void (and of course his answers to them), outlined in the remainder of proposition 35. Fabri raises four Aristotelian objections to motion in the void, all taken from book 4 of Aristotle's *Physics*, which outlines the Philosopher's adamant objection to the possibility of motion in the void, and consequently to the acceptability of the concept of void itself. These objections, as well as Fabri's answers to them, are described in the following section.

14.3 Attacking Aristotle's Objections to the Void

14.3.1 Objection 1 – Instantaneous Motion

This is the first objection to motion in vacuum that Fabri raises:

> You will say that the stone in that void would move instantly; because if the mobile moves faster, since it encounters a smaller resistance in a medium, it seems that it moves faster in the same proportion by which the aforementioned resistance is diminished; but a void designates an infinite decrease of resistance; therefore an infinite increase of velocity.[41]

It is no more than a reiteration of Aristotle's position, from *Physics*, book 4:

> Now the medium causes a difference because it impedes the moving thing... especially a medium that is not easily divided, i.e. a medium that is somewhat dense. A, then, will move through B in time C, and through D, which is thinner, in time E (if the length of B is equal to D), in proportion to the density of the hindering body. For let B be water and D air; then by so much as air is thinner and more incorporeal than water, A will move through D faster than through B. Let the speed have the same ratio to the speed, then, that air has to water. Then if air is twice as thin, the body will traverse B in twice the time that it does D, and the time C will be twice the time E. And always, by so much as the medium is more easily

i.e. keep the stone moving with constant speed and direction (Fabri 1669–1671, tr. 1, lib. 4, prop. 24, p. 252).

[40]See Gabbey 1998, pp. 652–653 for Beeckman's formulation of CRM, in which the application of the principle of sufficient reason is more explicit. There can be no doubt that Fabri was well aware of such formulations, most probably including Beeckman's.

[41]"Dices lapis in illo vacuo moveretur in instanti; quia si mobile movetur velocius, quod minorem in medio invenit resistentiam, videtur quod in ea proportione movetur velocius mobile, in qua praedicta resistentia imminuitur; sed vacuum dicit infinitum resistentiae decrementum; igitur infinitum velocitatis incrementum" (Fabri 1648, app. 1, prop. 35, p. 564).

> divided, the faster will be the movement. Now there is no ratio in which the void is exceeded by body, as there is no ratio of 0 to a number... Similarly the void can bear no ratio to the full, and therefore neither can movement through the one to movement through the other, but if a thing moves through the thickest medium in such and such a time, it moves through the void with a speed beyond any ratio.[42]

This "movement in an instant" argument – based on the widely accepted proportion $v \propto F/R$ (where $v =$ velocity; $F =$ weight or motive power; $R =$ resistance of the medium) – is only one of several consequences Aristotle describes as directly resulting from the idea of motion in the void (in which $R = 0$, i.e. v approaches infinity); their absurdity, claims Aristotle, is proof that this idea is itself totally ridiculous.

Before outlining Fabri's specific answer to this objection (explicitly taken from Galileo), it is important to remark that the attempt to refute Aristotle's proportion $v \propto F/R$ has a long and fascinating history. Already John Philoponus attacked Aristotle's proportion, and claimed that motion in a void is possible because resistance served merely to retard the motion of a moving object, i.e. caused it to need a longer time to pass a given distance than if it were moving in a vacuum.[43] His view could be interpreted – and indeed was, by later authors – as claiming that speed is proportional to the *difference* of weight and resistance, i.e. $v \propto F - R$, rather than to the *ratio* ($v \propto F/R$).[44]

A slightly different analysis – also allowing for motion in the void – was proposed in the 12th century by the Muslim philosopher Avempace (Ibn-Bajjah). Many of Avempace's works have not survived, but Averroes (Ibn-Rushd) – who for his part sided with Aristotle – mentions Avempace in his own commentary on Aristotle's *Physics*. Like Philoponus, Avempace attacks Aristotle's proportion $v \propto F/R$, and suggests the rule $v = v' - r$, where v is the velocity of the body in a resistant medium, v' its natural velocity in a void and r the retardation of the motion caused by the resistance of the medium.[45]

Ernest Moody has shown that Galileo's approach (following Benedetti's), in his early unpublished *De motu*, repeats Avempace's insight – that it is the difference (rather than ratio) between weight and resistance that counts – while containing also a deep Archimedean influence, which is manifest by using "specific gravity, conceived as an absolute value belonging to each body in virtue of its own nature", as a factor that determines a body's speed of fall in a void.[46] As Grant explains, "by introducing specific weight as the criterion for measuring the difference between body

[42] *Physics* [Aristotle 1930], 4, 8, 215a28–215b23.

[43] Grant 1964, p. 266, n. 5; Cohen and Drabkin 1948, pp. 217–221.

[44] Clagett 1959, pp. 434–435.

[45] Grant 1974, p. 257. It should be noted that Avempace's rather unclear rule was often (incorrectly) interpreted in the same way as that of Philoponus, i.e. $v \propto F - R$; it is also worth noting that according to Philoponus and Avempace, as well as the young Galileo in his *De motu* (and contrary to the "mature" Galileo in the *Two New Sciences*) bodies made from different materials do not fall with the same velocity in a vacuum.

[46] Moody 1951, p. 417. Furthermore, Galileo includes several theorems from Archimedes's treatise *On Floating Bodies* (Moody 1951, p. 413).

and medium", Galileo – following Benedetti – made Avempace's "vague law precise and intelligible" (Grant 1965, p. 360). Moody describes the interesting development of Avempace's theory, and explains that it was popular among many 13th century scholastics (Thomas Aquinas, Roger Bacon, Peter John Olivi, Duns Scotus) while several others supported Averroes (Albertus Magnus, Aegidius of Rome).[47] In the fourteenth century, the view that the velocity of a falling body depends on the difference (and not the ratio) between weight and resistance apparently fell out of grace. Many natural philosophers (e.g. Buridan and Nicole Oresme) adopted Thomas Bradwardine's interpretation of Aristotle proportion,[48] while others preferred (at least occasionally) the original proportion $v \propto F/R$.[49]

Fabri, for his part, rejects Aristotle's proportion while relying not on Galileo's *De motu* (which was not published but was widely distributed as a manuscript), but on Galileo's most important work, his *Two New Sciences*. This is Fabri's opinion on the old proportion $v \propto F/R$, supported by Aristotle, Averroes and their many followers:

> This argument is a mere paralogism, which led several [thinkers], even Aristotle himself, to an error, despite the fact that some [philosophers] try to justify the same Aristotle... I say that the proposed argument is of no value, nor is that [alleged] proportion of velocity to the resistance of the medium, as Galileo has excellently demonstrated.[50]

This is an unusually brave attack on Aristotle for a Jesuit, who is supposed to abide by Loyola's famous dictum to follow Thomas Aquinas in theology and Aristotle in philosophy, on quite an important issue. Perhaps most interestingly, Fabri recruits none other than Galileo himself – supposedly the "Great Enemy" of the Aristotelians in general, and the Jesuits in particular, at least following Galileo's trial – as an ally in this direct assault against the Stagirite. Fabri continues to explain why the proportion $v \propto F/R$ suggested by Aristotle is unacceptable:

> Otherwise (as he [Galileo] himself says) the same body, which moves through the medium of air, must also move through the medium of water, because there exists a proportion between the density, or resistance of air, and the density, or resistance of water; therefore, for example, a piece of wood would have to move through water, and through air, in the same proportion by which water is denser than air; i.e. motion[=velocity]-through-air to motion-through-water should be as resistance-of-water to resistance-of-air – and this is absolutely false; since from this it would follow, that the piece of wood moves in some sort of motion through the medium of water, and yet it cannot sink in water.[51]

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[47] Moody 1951, pp. 375–376.

[48] Anachronistically presented as $F_2/R_2 = (F_1/R_1)^{v2/v1}$. Moody 1951, p. 402; Grant 1965, p. 355; Clagett 1959, p. 438. On Bradwardine's influence, see also Clagett 1959, pp. 440–443.

[49] For example, Albert of Saxony employed Bradwardine's "function" in violent motion, but applied the simple formula of Aristotle and Averroes to natural motion (Grant 1965, p. 354).

[50] "Hoc argumentum est merus paralogismus, qui nonnullos, ipsumque adeo Aristotelem in errorem induxit, licet aliqui ipsum Aristotelem excusare conentur... Ad rationem vero propositam, dico nullam esse, nec enim est illa proportio velocitatis, quae resistentiae medii, ut optime demonstravit Galileus" (Fabri 1648, app. 1, prop. 35, p. 564).

[51] "Alioquin (ut ipse ait) idem corpus, quod movetur per medium aera, moveri etiam deberet per mediam aquam, quia datur proportio inter densitatem, vel resistentiam aeris, & densitatem, vel resistentiam aquae; igitur in ea proportione lignum v. g. deberet moveri per aquam, & aera, in

Now Fabri delineates his preferred proportion, taken from Galileo's *Two New Sciences*, which is (anachronistically) reconstructed as $(v_o - v)/v_o = \rho_m/\rho_b$:[52]

> Besides, if the body were twice as dense as the medium, then the medium subtracts half of the heaviness from the movable, therefore it would move through that medium with half the motion [i.e. velocity] which it would have had in the void;[53] therefore there would be no instantaneous motion in the void; if the movable were four times denser than the medium, then [the medium] subtracts a quarter of its heaviness; therefore [it subtracts] a quarter of the motion [velocity]; therefore if the motion [velocity] in the void were four [units], in the latter medium it will move [as fast] as three [units];[54] in the first medium, [as fast] as two [units];[55] therefore the motions [i.e. velocities] are in the ratio of 3/2 [between each other], even though the media are in the ratio 1/2.[56]

14.3.2 Objection 2 – Persistence of Projectiles

Another objection Fabri raises concerns projectiles:

> Because the stone, after being separated from the throwing hand, moves only because parts of the air impel it from behind; but in the void there is nothing which could harass from behind.[57]

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qua aqua est densior aere; ita ut motus per aera, sit ad motum per aquam, ut resistentia aquae, ad resistentiam aeris, quod falsissimum est; quia ex hoc sequeretur, lignum aliquo motu per mediam aquam moveri, cum tamen sub aquam descendere non possit" (Fabri 1648, app. 1, prop. 35, p. 564). It must be noted that the example of wood moving through air and water distorts Aristotle's thinking, because according to the Philosopher the concepts of "heaviness" and "lightness" have no practical meaning without discussing the medium involved. Aristotle sees no problem in regarding wood as in effect heavy in air (and therefore falls) but in effect light in water (and thus floats), and would of course adamantly reject as meaningless Galileo's and Fabri's claim that every object whatsoever, having only absolute heaviness (and no levity) would fall in a vacuum. Interestingly, Fabri adopts here Galileo's reading of Aristotle, which often does not fit the Aristotelian text itself.

[52] v = the speed of the falling body in medium m; v_o = the speed of fall of all bodies in a void; ρ_m = the specific weight of medium m; ρ_b = the specific weight of the falling body (see Galilei 1989, pp. 78–79, and Damerow et al. 2004, p. 270). Galileo's proportion from his *Two New Sciences* (1638) supposes, unlike the older version appearing in his *De motu*, that in vacuum all bodies fall in the same way, no matter the value of ρ_b.

[53] $v = v_o - v_o\rho_m/\rho_b = v_o(1-\rho_m/\rho_b) = v_o(1-1/2) = 0.5\ v_o$.

[54] Suppose v_o is equal (arbitrarily) to $4K$; if the body is 4 times denser than the medium ($\rho_m/\rho_b = 1/4$) then we should subtract $v_o\rho_m/\rho_b = 1K$; we would obtain $v = 4K - K = 3K$.

[55] If the medium is half as dense as the movable: $4K - 2K = 2K$.

[56] If we compare the two last examples (in the preceding two notes). Again, the obvious conclusion: the "equation" $v \propto W/R$ (or $v \propto \rho_b/\rho_m$) is wrong. "Praeterea si mobile sit duplo densius medio, medium detrahit mobili subduplum gravitationis, igitur movetur per illud medium motu subduplo illius, quo moveretur in vacuo; igitur in vacuo non esset instantaneus motus, si vero sit quadruplo densius mobile, medio, detrahit subquadruplum gravitationis; igitur subquadruplum motus; igitur si in vacuo motus sit ut quatuor, in hoc ultimo medio movebitur ut tria, in primo illo, ut duo; igitur sunt in ratione 3/2, licet media sint in ratione 1/2" (Fabri 1648, app. 1, prop. 35, p. 564).

[57] "quia lapis separatus a manu iacientis, ideo tantum movetur, quia partes aeris a tergo illum impellunt, sed in vacuo nihil est quod a tergo fatigare possit" (Fabri 1648, app. 1, prop. 35, p. 564).

This is how Aristotle formulated the same objection, clearly conveying his deep belief that the mechanism responsible for projectile motion must be connected to the medium:

> Further, in point of fact things that are thrown move though that which gave them their impulse is not touching them, either by reason of mutual replacement, as some maintain, or because the air that has been pushed pushes them with a movement quicker than the natural locomotion of the projectile wherewith it moves to its proper place. But in a void none of these things can take place, nor can anything be moved save as that which is carried is moved.[58]

Fabri's answer is short and straightforward, in keeping with the standard theory of impetus:

> The stone, after being separated from the hand, does not move because the air presses from behind, but rather because of the impressed impetus.[59]

Fabri's response echoes Buridan's claim that assuming an impressed impetus which is responsible for projectile motion "is evidently better than falling back on the statement that the air continues to move that projectile" (Clagett 1959, p. 534). However, what is interesting in this context is the difference in attitude between Fabri's *Metaphysica* and his *Tractatus*. While here in the *Metaphysica* Fabri does not hesitate to point out the contradiction between his view and Aristotle's, in the *Tractatus* he chooses to adopt a more conciliatory approach towards the Philosopher. In theorem 12 of the first book of the *Tractatus* (i.e. *De motu*) Fabri also denies Aristotle's claim that it is the air which impels the thrown stone, but adds that it might not have been Aristotle's real opinion, and that in any case, "the very words of Aristotle prove that he recognized a motive force impressed in the air, namely impetus".[60]

The following two objections are far more important than this one, and exemplify the distance between the scholastic (let alone Aristotle's) tradition and Fabri's physics, no doubt the direct result of the influence of *novatores* like Galileo and Descartes.

14.3.3 Objection 3 – Universal Velocity in the Void

Fabri raises another objection, taken also from book 4 of the *Physics*: "Because in a void everything would move with equal velocity, while diverse heaviness and shape seem to cause only the velocity's inequality".[61]

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[58] *Physics* [Aristotle 1930], 4, 8, 215a14–18.

[59] "[Responderi potest] non ideo lapidem a manu seiunctum moveri, quod aer insistat a tergo, sed propter impetum impressum" (Fabri 1648, app. 1, prop. 35, p. 564).

[60] "Aliqui excusant ipsum Aristorelem, putantque non esse locutum ex propria sententia: Alii dicunt Aristotelem quidem tribuisse aliquam vim extrinsecam aeri; non tamen negasse intrinsecam impetus; quidquid sit, ipsa verba Aristotclis demonstrant ipsum agnovisse vim motricem impressam aeri, hoc est impetum" (Fabri 1646, lib. 1, th. 12, p. 18).

[61] "Quia aequa celeritate cuncta ferrentur in vacuo, cuius tantum inaequalitatem, diversa gravitas, & diversa figura afferre videntur" (Fabri 1648, app. 1, prop. 35, p. 564).

Again, it is worth quoting Aristotle's words:

> To sum the matter up, the cause of this result is obvious, viz. that between any two movements there is a ratio (for they occupy time, and there is a ratio between any two times, so long as both are finite), but there is no ratio of void to full. These are the consequences that result from a difference in the media; the following depend upon an excess of one moving body over another. We see that bodies which have a greater impulse either of weight or of lightness, if they are alike in other respects, move faster over an equal space, and in the ratio which their magnitudes bear to each other. Therefore they will also move through the void with this ratio of speed. But that is impossible; for why should one move faster? (In moving through *plena* it must be so; for the greater divides them faster by its force. For a moving thing cleaves the medium either by its shape, or by the impulse which the body that is carried along or is projected possesses.) Therefore all will possess equal velocity. But this is impossible.[62]

Here is Fabri's reply:

> I say: firstly, that two bodies with different heaviness and the same shape and material are carried equally, as we proved in the second book of the *Tractatus physici*; secondly, as far as motion in a void is concerned, there is nothing relevant in what can be sought by the diverse ratio of media.[63]

As we already have seen in Part II, Fabri asserts – in corollary 2 of theorem 37 in the first book of the *Tractatus* (*De impetu*), regarding the speed of fall in *any* medium (including void) – that "a heavier body by itself (per se), at least of the same material, does not fall faster than a lighter [body], as a leaden ball of 100 pounds [does not fall faster] than a leaden ball of one pound". We have also noticed that in order to prove (or explain) this anti-Aristotelian notion he uses axiom 13 – "the extension of a cause does not strengthen an effect inwards (*ad intra*)" – and also (in theorem 37) his basic principle that impetus is not an efficient cause of motion but a formal cause (see Section 11.2 above). In book 2 of the *Tractatus* (*De motu naturali deorsum*) he claims again (incorrectly, according to modern physics, and also against Galileo) that things similar in shape and material but different in size fall exactly the same in every medium (see Section 11.2, Note 14 above). As for two bodies falling in a void, there is in any case – claims Fabri here in *De vacuo* – no difference of media, therefore no reason to assume a different rate of fall.

It must be noted that the arguments Fabri offers for the uniformity of motion in the void are less convincing than Galileo's ingenious explanation, deducing it while relying on the simple observation that "the difference of speed in moveables of different heaviness is found to be much greater in more resistant mediums" (Galilei 1989, p. 75). But it is also important to emphasize that Fabri's adoption of this assertion – using what could be described as an ad hoc argumentation – nevertheless reflects a significant break with the entire scholastic tradition. Edward Grant examined some major medieval philosophers who claimed, contrary to Aristotle,

[62] *Physics* [Aristotle 1930], 4, 8, 216a8–20.

[63] "Dico primo duo corpora diversae gravitatis, & eiusdem figurae, & materiae, aequaliter ferri, ut demonstravimus tom. 2 l. 2. Secundo ad motum in vacuo, nihil facit quidquam ex iis, quae a diversa mediorum ratione peti possunt" (Fabri 1648, app. 1, prop. 35, p. 564).

that motion in the void *was* possible, and noted that as was the case with the former two objections, all of them (as well as the young Galileo, in his *De motu*) have tried to refute this "paradox" as well, i.e. to prove that motion in the void does not entail universal equality of speeds (Grant 1964, p. 287). Bradwardine, for example, whose famous "function" (presented above) did not allow for motion in the void, claimed that "mixed" bodies – i.e. bodies not made of pure elements, which thus have "internal resistance" (e.g. a stone's levity resists its motion of fall) – *can* move in vacuum, and asserted that only homogenous (mixed) bodies of any size (i.e., of any weight) would move under such circumstances in equal speeds.[64] The mature Galileo – and following him, Fabri – preferred instead to fully incorporate this "absurd" (universal equality of speeds) into their physical systems.

14.3.4 Objection 4 – CRM

The last objection Fabri raises against motion in the void is the most interesting in the context of Fabri's inertial thinking. Fabri says simply: "A stone once thrown would move indefinitely".[65] Fabri of course is again only reiterating Aristotle's argument – another one of the "paradoxes" allegedly resulting from motion in the void:

> Further, no one could say why a thing once set in motion [in the void] should stop anywhere; for why should it stop *here* rather than *here*? So that a thing will either be at rest or must be moved *ad infinitum*, unless something more powerful gets in its way.[66]

Here Aristotle directly refers to what amounts more or less to CRM (or "inertia") as a "paradox". Aristotle, who does not even bother to explain why this notion is so ridiculous, must deem it a paradox since any resistless motion is impossible (as we saw, Aristotle's proportion $v \propto F/R$ entails infinite velocity under zero resistance) and inexplicable (we also know that Aristotle actually uses the medium to *explain* projectile motion). Moreover, and even more importantly, according to Aristotle violent motion can never be eternal. While discussing in the first book of *On the Heavens* the natural circular motion of the heavens, he says that if this movement were said to be violent, it would be "strange, in fact quite absurd, that being unnatural it should yet be the only continuous and eternal motion, seeing that in the rest of nature what is unnatural is the quickest to fall into decay." In the second book he remarks that this "natural motion is circular. Otherwise the motion would not

[64] Grant 1965, pp. 345–349. Galileo, in his *De motu*, arrived at a similar conclusion, not limiting it of course to "mixed" objects; Galilei 1960, pp. 48–49. However, Grant warns us not to regard Galileo's *De motu* (which in effect abandons levity) as influenced by Bradwardine's view, that sees levity as an internal resistance (to a falling body) and thus preserves "the fundamental Aristotelian principle that motion is only maintained and continued by the conjoint action of a motive force and a resistance" (Grant 1965, p. 349 n. 17, pp. 357–359).

[65] "Lapis semel iactus semper moveretur" (Fabri 1648, app. 1, prop. 35, p. 564).

[66] *Physics* [Aristotle 1930], 4, 8, 215a19.

be eternal, for nothing contrary to nature is eternal. The unnatural is subsequent to the natural, being an aberration from the natural in the field of becoming".[67] And finally, straight motion – whether natural or violent – can never be, by definition, *ad infinitum*: it must have both a *terminus a quo* and a *terminus ad quem*.[68]

Grant, in his abovementioned article, has noted that while the medieval philosophers he examined treated the first three Aristotelian objections ("paradoxes") described here, they all avoided the fourth one, the "inertial" paradox. "Why," asks Grant, "was this argument not also repudiated, or at least discussed by those who insisted that motion in the void was not absurd?" He suggests as a possible answer that according to scholastic cosmology the universe is in any case limited, so this argument was not considered relevant or interesting. We have seen that according to Fabri the universe is immersed in an infinite void, so evidently as far as he is concerned this argument *is* pertinent and meaningful. Grant further estimates (very reasonably) that *had* this argument been discussed by the scholastics, "it seems almost certain that Aristotle's consequence would have been denied, for, otherwise, every violent motion in the void would have been of an inertial character" (Grant 1964, pp. 288–289).

It seems that this "anti-inertial" climate lasted until Fabri's time (or at least very close to it): in the influential commentary to the *Physics* by the Jesuit *Collegium Conimbricenses*, this "inertial consequence" is recognized as a necessary result of assuming that the impetus is conserved and that motion in the void is possible (and even "easy"), but casually dismissed as "an absurd" because "no motion can begin" in the first place within such a void.[69] Fabri's "thought experiment", in which a void is created only *after* motion has already begun, renders this evasion useless.

This "anti-inertial" frame of mind, a major characteristic of seventeenth century Aristotelian physical thinking, was no doubt grounded in the long-standing ingrained aversion to the possibility of eternal violent motion. Buridan could be presented as "wavering" concerning the possibility of *natural* motion in the void: he claims, in his *Physics* commentary, that such motion is naturally impossible, but might occur by divine intervention;[70] however, never does he discuss (even

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[67] *On the Heavens* [Aristotle 1953], 1, 2, 269b5–269b8 & 2, 3, 286a19–286a22, in Aristotle 1953.

[68] *Physics* [Aristotle 1930], 8, 9, 265a14–265b1. See also Gabbey 1998, pp. 660–661 and Damerow et al. 2004, p. 264, n. 182.

[69] "Quare aut semper quiescit, aut si motum semel arripuerit, perpetuo fluctabit; quod absurdum est. Neque recte Philosophantur dum in vacuo eam ad motam inesse commoditatem inquiunt, quod facile cedat, & impetum nequaquam demoretur, cum ostensum sit nullum in eo motum iniri posse" (Conimbricenses 1594, lib. 4, qu. 5, art. 3, p. 54). In fact, this "anti-inertial" sentiment remained alive, within Jesuit circles, even in the dawning of the eighteenth century (see the Chapter "Conclusion" below, Note 7)

[70] I think that Grant is correct in claiming that this statement cannot be seen as a shift of mind towards accepting motion in vacuum, since the assumption that a heavy body can move in vacuum has already been rejected by Buridan; thus, being based on this false assumption, Buridan's further discussion concerning natural motion (which favourably mentions Avempace's abovementioned view) should be deemed entirely hypothetical and not representing Burdian's real opinion (Grant 1964, pp. 279–280).

in this highly hypothetical context) the possibility of *violent* motion in vacuum.[71] The seventeenth century Aristotelian resistance to this possibility is exemplified, for example, in the following objection, uttered by Galileo's Simplicio (in the *Dialogue*) to the possibility of the moving Earth:

> If the Earth moves either in itself about its own centre or in a circle around the centre, it is necessary that that motion be violent, for it is not its natural motion; for, if it were, each of its parts would partake thereof; but each of them moves in a straight line towards the centre. It being therefore violent and preternatural, it could never be perpetual. But the order of the world is perpetual. (Galilei 1953, p. 138)

The same resistance also appears (with emphasis) in the following passage written by the English philosopher and physician Walter Charleton, in which he depicts a "thought experiment" very similar to Fabri's:

> If a stone placed in the empty Extramundane spaces should be impelled any way, the motion thereof would be continued the same way, and that uniformly or equally, and with tardity or celerity proportionate to the smartness or gentleness of the impulse, and perpetually in the same line; because in those empty spaces it could meet with no cause, which by diversion might either accelerate or retard its motion. *Nor ought it to be objected, that nothing violent can be perpetual*; because, in this case, there could be no repugnancy or resistance, but a pure indifferency in the stone to all regions, there being no centre, in relation whereunto it may be conceived to be heavy or light.[72]

Fabri, deeply influenced by Galileo and Descartes, had no problem whatsoever with (potential) eternal violent motion. He chose not to ignore the "inertial" consequence of motion in a void (like his distant scholastic predecessors), nor to avoid it (like his Jesuit immediate forerunners, and probably many of his colleagues); he simply accepted it (like the third "paradox") as part of physics. His response in the *Metaphysica* to the fourth objection is short and decisive: "I concede, of my own accord, that in a total void a stone once moved, would move indefinitely, unless it is restrained extrinsically".[73]

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[71] See Toth 2010, p. 66 (Toth's subsequent discussion – ibid., pp. 66–69 – conveys a view which differs from Grant's or mine).

[72] Charleton 1654, p. 466; Charleton's emphasis.

[73] "Concedo ultro fore, ut in totali vacuo lapis semel motus, semper moveatur, nisi ab extrinseco retineatur" (Fabri 1648, app. 1, prop. 35, p. 564).

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Chapter 15
The Inherent Linearity of Impetus

As we have seen in Section 14.2 above, Proposition 35 from the *Metaphysica* begins by claiming that in a void "nothing would impede a power of a motive force, determined along such a line," implying a rectilinear conservation of impetus and motion. Fabri's analysis of horizontal projectiles (to be discussed in Section 16.2 below) starts by assuming that in the absence of gravity such a projectile "would obviously move along a straight line with constant motion", leaving no doubt that Fabri had in mind CRM, and not anything like "circular inertia" which Copernicus, Gassendi, and others attributed to bodies.

15.1 Impetus and *determinatio*

In book 12 of the *Metaphysica* Fabri remarks that "since motion follows from impetus, it is determined along one line only, whether it is simple, or mixed, and that determination was extensively dealt with in the first book of the *Tractatus physicus*".[1] Indeed in the *Tractatus* we can clearly observe that the origin of Fabri's "rectilinear" attitude is the very nature of impetus itself: like Benedetti before him Fabri explicitly rejects any impetus which is not rectilinear.[2] Theorem 45 claims that "the impetus does not act simultaneously along a circle,[3] rather only along the line of its motion"; later Fabri points out:

[1] "Cum motus sequatur ex impetu, hic ad unam tantum lineam est determinatus, sive simplicem, sive mixtam, de hac determinatione fuse actum est tom. 2. l. 1" (Fabri 1648, lib. 12, prop. 20, p. 496).

[2] As mentioned above, in 1585 Benedetti came quite close to CRM. See the beginning of Chapter 14 (especially Note 7), and also Clagett 1959, pp. 663–664; Koyré 1978, pp. 21–27.

[3] The full meaning of this rather obscure remark – *Non simul agit impetus in orbem* – will be explained in Section 15.2 below.

M. Elazar, *Honoré Fabri and the Concept of Impetus: A Bridge Between Conceptual Frameworks*, Boston Studies in the Philosophy of Science 288,
DOI 10.1007/978-94-007-1605-6_15,

> You will observe... that the impetus, in each of its two causal roles,[4] is under one line only; i.e. it exacts motion through a single line; because there cannot be motion through many [lines] at once; otherwise the same mobile would be in many places at once.[5]

Later in the first book of the *Tractatus* Fabri says:

> Theorem 112: an impetus must be determined along a certain line of motion; it is proved, because there cannot be an impetus, unless it exacts motion... and it can exact motion only along a certain line, which is clear; but this means that the impetus is determined along a certain line of motion; besides, if it is not determined along a certain line; therefore it is undetermined and indifferent by axiom 5. But it cannot stay indifferent; for why would it prefer motion along one line, rather than another? Therefore it must be determined.[6]

An impetus therefore has to be determined, i.e. aligned along a specific line. Fabri's conception of *determinatio* enables him to treat the concept of impetus as if it were a vector: "You will observe first of all," says Fabri, "that this determination is nothing other than this very impetus adapted, or conjoined, to such a line".[7] Later (in theorems 137–142) Fabri develops a sort of a "vector analysis" to explain how various pairs of "determined" impetuses at varying angles to each other are to be added and to estimate the resultant traversed space. The nature of this "vector analysis" will be explained later in this part, within the discussion concerning Fabri's theory of projectile motion.

The concept of *determinatio* has deep origins and a varied range of meanings. As Allan Gabbey explains, "in classical Latin *determinatio* denotes broadly a bounding or limitation by means of *termini*" (Gabbey 1980, p. 248). Lucretius employs the verb *determinare* to describe Jupiter directing the thunderbolts he hurls; Diophantus uses the term *determinatio* to denote "a further condition" in a problem he discusses in his *Arthimetica*; Thomas Aquinas sees it as "a particular actualization or realization of some general power" and also as "the first principle of plurality",

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[4]The first role is to "exact" motion *ad intra*; the second role is to "create" a new impetus *ad extra* in another body following a collision.

[5]"Non simul agit impetus in orbem sed tantum per lineam sui motus... Observabis tertio, impetum in utroque munere causae subesse tantum uni lineae; scilicet exigit motum per unam lineam; cum per plures simul motus esse non possit; ne idem mobile simul esset in pluribus locis" (Fabri 1646, lib. 1, th. 45, pp. 32–33).

[6]"Impetus debet determinari ad aliquam lineam motus; probatur, quia non potest esse impetus, nisi exigat motum per Th. 14, nec exigere motum, nisi per aliquam lineam, ut patet; sed hoc est impetum esse determinatum ad aliquam lineam motus; praeterea si non est determinatus ad aliquam lineam; igitur indeterminatus, & indifferens per Ax. 5. Sed indifferens manere non potest; cur enim potius haberet motum per unam lineam, quam per aliam? igitur debet determinari" (Fabri 1646, lib. 1, th. 112, pp. 60–61). The text says "per Ax. 1", but since axiom 1 discusses a completely different matter, and it is axiom 5 which asserts that what is "one" is also "determined" and "not indifferent", it must be a typo.

[7]"Observabis primo determinationem hanc nihil esse aliud, nisi ipsum impetum cum tali linea comparatum, seu coniunctum" (Fabri 1646, lib. 1, th. 114, scholium, p. 61). Gideon Freudenthal demonstrates Fabri's preference (on account of ontological considerations) to regard impetus itself as a scalar magnitude, rather than a vector, while using nonetheless the parallelogram rule; Freudenthal 2000, pp. 130–135. In any case, we just saw that the impetus "cannot stay indifferent" and has to become "determined," i.e. directed along a line.

while he applies the adjective *determinatus* "to what is specified or settled in some sense".[8]

Fabri asserts, in axiom 5 of *De impetu*, that "what is one, is determined (*determinatum*), because what is one is 'this', and nothing else, for 'one' is none other than being undivided in itself and divided by something else", while "indifference (*indifferentia*), or indetermination (*indeterminatio*) exists only where there are many". "If there is only one", claims Fabri, "certainly it is not indifferent".[9] And as we have just seen, it is axiom 5 which Fabri refers to in theorem 112, which claims that impetus cannot stay indifferent (undetermined), but must become determined – that is, directed along a specific line.

Gabbey remarks that prior to Descartes, the term *determinatio* was not used within mechanics, "that is, mechanics as opposed to mathematics, particularly geometry".[10] Indeed, Fabri's use of this term is heavily influenced by Descartes – whose law of refraction from the *Dioptrics* is explicitly mentioned, expressing admiration, in the *Tractatus*.[11] As for Descartes' notion of *determinatio* – this issue has posed many problems to his contemporaries, not to mention modern historians: "Despite the multiplicity of studies on Descartes' mechanics", complains Gabbey, "particularly his rules of collision, no really satisfactory account of this knotty conception has ever been given, not even by Descartes himself" (Gabbey 1980, p. 248). Another important source asserts that "Descartes is probably the only person who ever used his concept of determination productively in physics… It was not an everyday tool that could be used by any competent scientist; it was an idiosyncratic instrument that could be employed only by its inventor".[12] However, what is not disputed among researchers – concerning Descartes' elusive concept of *determinatio* – is that "it refers to the further specification of a concept, for instance, the determination of a species within a genus. In particular, a determination is the modification of a predicate, the qualification of a quality".[13] As far as mechanics is concerned, *determinatio* can be defined as a directional mode of motion that designates what we would define as the "vector" of motion; while Descartes sees motion as a mode of matter, *determinatio* is in his eyes a mode of this mode.[14] We have recently seen that Fabri regards *determinatio* as an *impetus* "adapted, or conjoined" to a line, but as we shall soon see he actually uses this concept not as an "impetus

[8] Gabbey 1980, pp. 248–249 and p. 309 (n. 99).

[9] "Quod unum est, determinatum est. Quia quod unum est, est hoc,& nihil aliud; nihil enim aliud est unum, nisi indivisum in se, & divisum a quolibet alio: quippe indifferentia, vel indeterminatio ibi tantum est, ubi sunt plura… si enim tantum unus est, certe indifferens non est" (Fabri 1646, lib. 1, ax. 5, p. 6).

[10] Gabbey 1980, p. 249, and p. 309, n. 99.

[11] "…etiam ex hoc phaenomeno duci potest vera mensura, seu regula refractionum, quod ingeniosissime excogitavit vir illustris Renatus Descartes in sua *Dioptrica*" (Fabri 1646, lib. 6, th. 85, p. 264).

[12] Damerow et al. 2004, p. 131.

[13] Damerow et al. 2004, p. 109.

[14] Damerow et al. 2004, pp. 80, 109.

vector", but as what we would call a "velocity vector", having both size and direction, while two determinations of different directions are "mixed" in accordance with the parallelogram law.

Fabri uses his notion of *determinatio* mainly in the context of collisions. Regarding impacts between balls, he uses also the terms "resistance" (*resistentia*) and "yielding" (*cessio*), but in his analysis of reflection from totally elastic planes Fabri employs the term *determinatio* alone; it is therefore worthwhile – in order to better understand Fabri's *determinatio* – to examine his explanation of reflection from such unyielding surfaces; such an examination will also provide us with a deeper glimpse into his "inertial" way of thinking.[15]

Theorem 40 of book 6 of the *Tractatus*, *De motu reflexu*, examines what happens when an object hits an unyielding plane MR at point D (Fig. 15.1). At the beginning of this theorem Fabri discusses the case of perpendicular collisions: "The *determinatio* through DG", i.e. the *determinatio* which the plane exerts on the object hitting it perpendicularly at D, "is twice the *determinatio* before the reflection along the line of incidence GD". While proving this assertion Fabri examines oblique reflections – i.e. along the incident lines ID, AD etc. – and each time finds the *determinatio* that has to be exerted by the plane in order to form (according to the parallelogram law) the desired outcome. For instance, if the line of incidence is ID, then the *determinatio* of the hitting object is DO (OI of course defines a diameter). Assuming the equality of the angle of incidence (angle IDR) and the angle of reflection (angle NDM), then in order to obtain DN we should add (according to the parallelogram GDON)[16] the *determinatio* DG – therefore, claims Fabri, the *determinatio* which the plane exerts must be DG (which in this case is equal to AD). Similarly, if the line of incidence is AD, then inspecting the relevant parallelogram DEHT, it is obvious that the plane must exert DT (which is now bigger than the original AD) in order to result – together with DE – in DH (assuming that angle ADR equals to angle HDM). As Lukens explains, "by extrapolation, when the line of incidence is perpendicular, or GD, and the *determinatio* is Dδ, the line of reflection is DG, and the *determinatio* from the plane is DY, equal to δG. But δG is twice GD, which was to be proven".[17]

An immediate question arises: how does Fabri justify the assumption that the angle of incidence is equal to the angle of reflection? This is a well known fact, which has been "illustrated at least since Alhazen (Ibn al-Haytham) with geometrical figures displaying the composition of motions"[18] and of course proven by Descartes in his *Dioptrics*. Lukens claims that "as far as I can tell, Fabri takes from experience the equality of the angle of incidence and the angle of reflection" (Lukens 1979, p. 236). However, Fabri himself never says such a thing: to justify

[15] Lukens provides a fuller account of Fabri's theory of collisions (Lukens 1979, pp. 233–246).

[16] DO should be parallel and equal to GN, though unfortunately this is not so obvious in the figure Fabri supplies.

[17] Fabri 1646, lib. 6, th. 40, pp. 245–249. See also Lukens 1979, pp. 235–236.

[18] Damerow et al. 2004, p. 114. In the field of optics, this principle "was known in the fourth century B.C., and no doubt earlier"; Clagett 1955, p. 102.

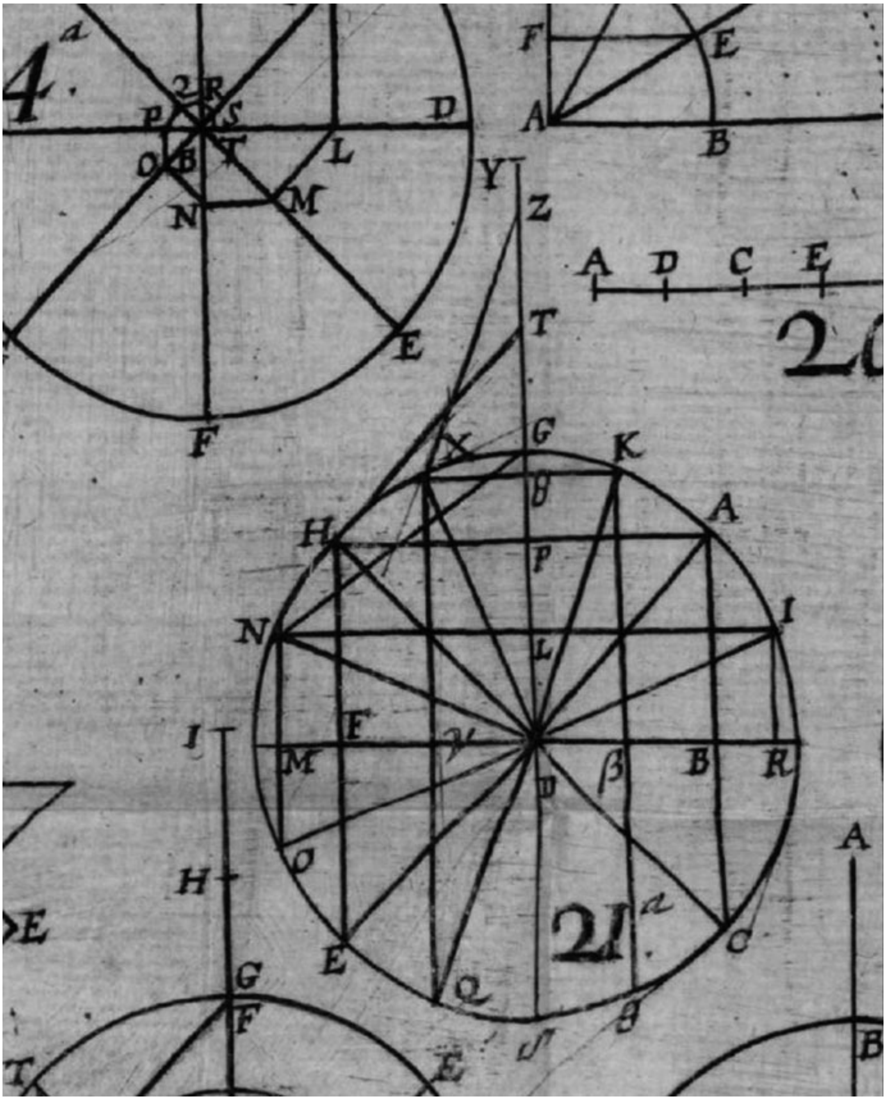

Fig. 15.1 An object hitting an unyielding plane (figure 21; Fabri 1646, tabula III)

his assumption the Jesuit refers the reader to theorem 33,[19] which is itself based on previous theorems. Essentially Fabri has claimed that the new *determinatio* produced by the plane on the hitting object[20] depends on the impediment which the

[19]"Hinc angulus reflexionis est aequalis angulo incidentiae" (Fabri 1646, lib. 6, th. 33, p. 243).

[20]Not to be confused with the *determinatio* exerted by the wall on the plane, which was mentioned just above, and should be vectorially added to the original *determinatio* in order to obtain the final outcome.

former causes the latter, and this reaches its highest possible value when the impact is perpendicular: “When the line of incidence”, explains Fabri in theorem 22, “falls perpendicularly on the reflecting plane the impediment is maximal; for the blow is maximal, as we have proven in the first book”.[21] When the line of incidence is oblique, “the impediment is smaller, because the blow is smaller… the blow along line GD is to the blow along line AD as AD is to AB”.[22] To substantiate this claim Fabri relies on his analysis of the inclined plane, which has shown that the weight which an object lying on an inclined plane exerts depends on the sine of the angle of inclination.[23] This enables Fabri to assert, in theorem 32, that “hence the *determinatio*, which the plane confers, decreases according to the versed sines (*sinus versi*) in GD. For example, let the line of incidence be AD; let there be drawn APH parallel to FB: the *determinatio* which the plane confers decreases by the versed sine PG”.[24]

Since $\text{versine}(\theta) = 1\text{–}\cos(\theta)$,[25] Fabri means that as θ decreases (therefore, as the angle of incidence increases), so does the *determinatio* which the plane confers increase: at $\theta = 0$, where the angle of incidence is 90°, the value of the versed sine is zero and the plane confers the highest *determinatio*.

But the *determinatio* that the plane confers on the hitting object – which is of course always perpendicular to the plane – is only one part of the picture: as Fabri explains, the line of reflection which results from an oblique line of incidence is also affected by the horizontal part that remains from the original *determinatio*. For example, concerning the line of reflection DH, which results from the line of incidence AD: “this line is not determined by plane FB alone, otherwise it would be DG, and it is not the same as the first, otherwise it would be DE; it is rather partly determined by plane FB along DG and partly retains something of the first determination, and by both DH is made, as is clear, because the more oblique the line of incidence, the less the plane determines”.[26] Fabri now asserts that “in the proportion by which the plane less confers a new *determinatio*, it retains more of the

[21] “Quando linea incidentiae cadit perpendiculariter in planum reflectens est maximum impedimentum; quia scilicet est maximus ictus, ut probavimus lib. 1” (Fabri 1646, lib. 6, th. 22, p. 241); Fabri means theorems 50 and 55 in *De impetu*.

[22] “Quo linea incidentiae cadit obliquius in planum, est minus impedimentum, quia est minor ictus… ictus per lineam GD est ad ictum per lineam AD, ut AD ad AB” (Fabri 1646, lib. 6, th. 23, p. 241).

[23] Fabri 1646, lib. 6, th. 23, p. 241. Fabri refers to theorem 16 of book 5, *De motu in diversis planis*, p. 202. This claim is very similar to Jordanus of Nemora’s concept of “Positional Gravity”, discussed in Clagett 1959, pp. 74–75.

[24] “Hinc decrescit determinatio, quam confert planum iuxta rationem sinuum versorum in GD. v. g. si sit linea incidentiae AD; ducatur APH parallela FB, determinatio quam confert planum, decrescit sinu verso PG” (Fabri 1646, lib. 6, th. 32, p. 243).

[25] Assuming that θ represents the angle between the line of incidence and the perpendicular to the plane, e.g. the angle GDA in the case of the incident line AD.

[26] “v. g. sit linea incidentiae AD, linea reflexionis DH; non tantum determinatur haec linea a plano FB, alioqui esset DG, nec est eadem cum prima; alioqui esset DE, sed partim determinatur a plano FB per DG partimque retinet aliquid primae determinationis, & ex utraque fit DH, ut constat, quia quo linea incidentiae est obliquior, planum minus determinat” (Fabri 1646, lib. 6, th. 29, p. 242).

first *determinatio*", because when the impact is perpendicular, nothing remains of the original *determinatio*, while if the line of incidence is parallel to the plane – i.e. no impact will result – naturally the original *determinatio* will stay intact. Fabri deduces that at different lines of incidence – i.e. in all the intermediate cases – "each of them confers to the new *determinatio* in proportion (*pro rata*)".[27] Fabri translates this qualitative statement to the assertion that "the portion of the first *determinatio* of the line of incidence increases according to the vertical sines [*sinus recti*, i.e. regular sines] in BD, e.g. if the line of incidence is AD, it increases by the vertical sine AP equal to BD; if it is ID, it increases by the vertical sine IL or RD".[28] Only now – i.e. in theorem 33, immediately after establishing that the *determinatio* conserved is equal to the horizontal component belonging to the *determinatio* of any line of incidence (e.g. AP = PH) and that the *determinatio* conferred by the plane depends on the vertical component of the original *determinatio* – does Fabri assert the inevitable conclusion (which he proves by a simple congruence of triangles) that the angle of reflection is equal to the angle of incidence.[29]

In other words, Fabri does not – as Lukens claims – "take from experience" this equality, but rather bases it on his former standard analysis of weights on inclined planes (akin to Jordanus's "Positional Gravity"), along with his basic contention that the impetus exerted by an object hit by another is as big as the impediment which it represents (and therefore maximal at a perpendicular impact), and a common sense assumption that the *determinatio* conferred by the plane decreases by the same proportion in which the *determinatio* that remains from the original one increases.

Fabri's argumentation seems reasonable enough; however, it is surprising – considering the established fact that Fabri is perfectly aware of CRM – that he does not simply state (within proving the equality between the angle of incidence and the angle of reflection) that the horizontal *determinatio* is conserved. This is what Descartes says, in his *Dioptrics*; discussing the *determinatio* of the object (a tennis ball) downwards towards the plane, he asks the rhetorical question "why should it hinder the other one, which made the ball advance towards the right, seeing it is in no way opposed to [the ball] in that direction?"[30] Fabri's refusal to deal separately with the "inertial" horizontal component of the motion – preferring to derive its conservation only after examining the behavior of the vertical component (by

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[27]"Hinc qua proportione planum minus confert ad novam determinationem, plus remanet prioris determinationis; quo vero plus illud confert, huius minus restat; hinc, cum planum totam confert novam determinationem ut in perpendiculari DG, nihil prioris remanet; hinc si linea incidentiae sit parallela plano BF nulla fiet nova determinatio, tota priore intacta; si vero sit perpendicularis GD, tota determinatio est nova, & nihil prioris remanet; si demum lineae incidentiae sint aliae, confert utrumque ad novam determinationem pro rata" (Fabri 1646, lib. 6, th. 30, p. 243).

[28]". . . at vero crescit portio prioris determinationis lineae incidentiae iuxta rationem sinuum rectorum in DB, v. g. si sit linea incidentiae AD, crescit sinu recto AP aequali BD, si sit ID crescit sinu recto IL vel RD" (Fabri 1646, lib. 6, th. 32, p. 243).

[29]Fabri 1646, lib. 6, th. 33, p. 243.

[30]Quoted in Gabbey 1980, p. 252.

claiming that "in the proportion by which the plane less confers a new *determinatio*, it retains more of the first *determinatio*") – is also evident in Fabri's analysis of projectile motion (discussed later in this part), in which Fabri flatly rejects the important principle of superposition.

15.2 Circular Motion: An "Impeded" Straight Motion

Having seen Fabri's view concerning reflecting elastic planes, let us return to the central issue of the inherent linearity (i.e. being necessarily *determinatus*) of impetus, which leads him to outline quite an advanced approach to circular motion, including the important recognition that an object tied to a turning rope which then breaks will proceed along a straight line. Already in the synopsis, Fabri declares: "Circular motion in sublunar things emerges from an impeded straight line; because the impetus is determined only along a straight line: hence any circular motion exists merely by accident, such as the end of a pendulum or a sling which is restrained; if it is released, a straight motion follows".[31] This important idea, which within Gassendi's thought is muddled with "circular inertia" (Palmerino 2004, pp. 151–152), does exist – explicitly and unequivocally – in Fabri's analysis (and also in Descartes' and Galileo's), and it is indeed a far cry from Buridan's claim that impetus can be directed "either up or down, or laterally, or circularly".[32]

The seventh book of the *Tractatus*, entitled *De motu circulari*, deals with circular motion. The first theorem attempts to "prove" that circular motion exists, and as usual, Fabri divides this "proof" into a factual (or experimental) part and a theoretical ("*apriori*") one. Circular motion is first "proved", explained Fabri, by observing the motion of balance arms and levers around their fulcrum, as well as millstones, tops and pendulums.[33] The theoretical part of this proof is perhaps more interesting, and invokes what would be defined in classical physics as a "couple" (of forces) creating a pure moment: Fabri presents cylinder CL (Fig. 15.2), in which an equal impetus is applied in opposite directions to each extremity: along CP in C and along LM in L. The result has to be, as Fabri explains, circular motion around the center K, in which while C moves along arc CE, L sweeps arc LB. Because the impetuses are equal, neither can prevail over the other, so motion along the tangents CP or LM

[31]"Motus circularis in sublunaribus oritur ex recto impedito; quia, scilicet, determinatur tantum impetus ad lineam rectam: hinc quidam motus circularis est mere per accidens, ut cum retinetur extremitas funependuli, seu fundae, quae si demittatur, sequitur motus rectus" (Fabri 1646, "Synopsis amplior", "De motu circulari," par. 1; this section of the *Tractatus* is unnumbered).

[32]Clagett 1959, p. 534. See also beginning of Section 5.3 above.

[33]"Theorema 1: Datur motus circularis. Probatur infinitis fere experimentis; primo in libra cuius brachia motu tantum circulari descendunt. Secundo in vecte, qui etiam movetur circulari motu; Tertio in turbine, rota molari, liquore contento intra vas sphaericum; Quarto in funependulo vibrato" (Fabri 1646, lib. 7, th. 1, p. 273).

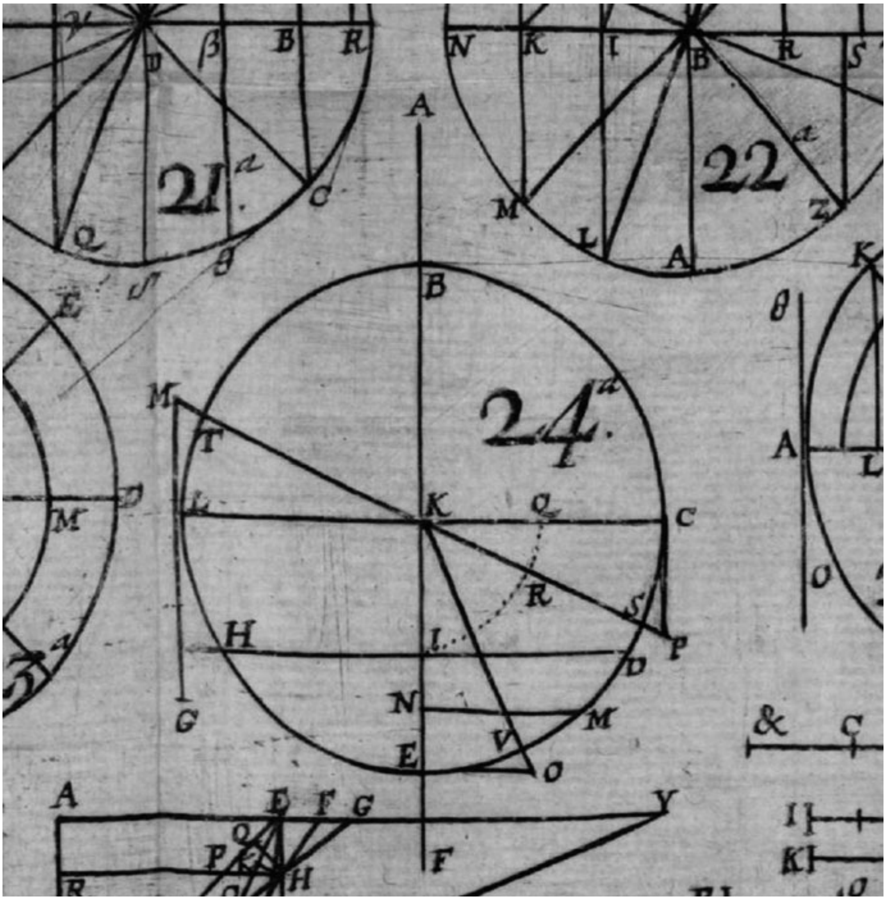

Fig. 15.2 Creation of circular motion (figure 24; Fabri 1646, tabula III)

would be impossible, and necessarily the resulting motion would be along the arcs such as LT and CS.[34]

In theorem 2 Fabri develops the general idea presented in the first theorem (that circular motion is somehow brought about from a frustrated attempt to produce linear motion), and thus also clarifies his somewhat strange assertion that "*non simul*

[34] "Probatur secundo; quia potest imprimi impetus utrique extremitati cilindri in partes oppositas, sit enim cilindrus, vel parallelipedum LC, cuius extremitati imprimatur impetus, per lineam CP, itemque extremitati L aequalis per lineam LM [page 273 says 'LG', but it is corrected in the errata into 'LM'. M. E.] oppositam Cp. Dico, quod movebitur circulariter circa centrum K, ita vt extremitas L conficiat arcum LB & C arcum CE; nec enim C moveri potest per CP neque L per LM; quippe cum sit aequalis impetus, neutra extremitas praevalere potest: non utraque, quia MP est maior LC; nec dici potest neutram moveri, cum moveri possit L per arcum LT, & C per arcum CS" (Fabri 1646, lib. 7, th. 1, p. 273).

agit impetus in orbem" (Note 3 above). Fabri claims here that "at least in sublunar things", circular motion would not exist unless "a determination of impetus along a straight line was impeded". For example, in Fig. 15.2, if the linear *determinatio* of the impetus applied in point L along LM were not impeded, it would not move along arc LB, but would remain rectilinear along LM.[35]

By claiming that circular motion in nothing but a result of a "frustrated" (or degenerated) linear motion, Fabri in fact rejects Aristotle's basic conviction that "circular motion is primary to all others, because it is simpler and more complete" (Gabbey 1998, p. 661). Hence, Fabri continues to explain in the following theorems, "a circular motion arises from a straight one impeded in single points," and therefore in each instant it is "determined along a new line." Fabri concludes that "there are as many determinations corresponding to single instants as there are tangents in a circle" and that at each point the circular motion is "determined towards a new tangent".[36] As for non-circular curved motion, Fabri identifies it with a "mix" between straight and circular motions, and asserts that a curved line is nothing but a line composed of "almost infinite sides of a polygon".[37] We may therefore ascribe to Fabri a sort of a reduction of all motion to basic rectilinear motions, a reduction which is physically justified by his assertion that in a given mobile several motions cannot exist at once, and that any "mixed motion" arises from the interaction between the impetuses within it, which as we have seen are always "rectilinear".[38]

It is important to stress though that Fabri limited this inherent "linearity" of motion to terrestrial, i.e. sublunary physics. We have just seen that in the beginning of *De motu circulari* Fabri remarks that he refers to sublunary motions "at least," thus casting a doubt concerning heavenly motions. However, soon afterwards he explicitly rejects heavenly linear tendencies and adheres to traditional circular non-terrestrial motions.[39]

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[35] "Theorema 2: Nisi impediretur impetus determinatio per lineam rectam, non daretur motus circularis saltem in sublunaribus. v. g. nisi impediretur determinatio impetus, qui inest puncto L per lineam LM; haud dubie non moveretur per arcum LB, sed per rectam LM; igitur ille motus non esset circularis" (Fabri 1646, lib. 7, th. 2, p. 273).

[36] "Theorema 3: Hinc motus circularis oritur ex recto impedito in singulis punctis... Theorema 4: Hinc singulis instantibus punctum dum movetur circa centrum K determinatur ad novam lineam... Theorema 5: Hinc tot sunt determinationes singulis instantibus respondentes, quot sunt Tangentes in circulo; quippe in singulis punctis determinatur ad Tangentem; sed impeditur denuo pro sequenti instanti; igitur ad novam Tangentem determinatur" (Fabri 1646, lib. 7, ths. 3–5, pp. 273–274).

[37] Fabri describes curved motion as "mixtus ex recto & circulari" (Fabri 1646, lib. 9, th. 27, p. 364); the second postulate of the 4th book claims: "Illa linea vocetur curva quae constat infinitis prope lateribus polygoni" (Fabri 1646, lib. 4, post. 2, p. 154).

[38] "Motum mixtum eum esse non dico, qui ex pluribus aliis motibus componatur; seu misceatur; nec enim plures motus simul esse possunt in eodem mobili... Motus mixtus est, qui sequitur ex multiplici impetu ad eamdem, vel diversas lineas determinato, vel eodem ad diversas" (Fabri 1646, lib. 4, p. 153; before the first definition).

[39] "observabis dictum esse supra in sublunaribus quia corpora coelestia moventur motu circulari non habita ulla ratione motus recti" (Fabri 1646, lib. 7, th. 3, p. 273).

Fabri's concept of inherently rectilinear impetus, as exemplified in his reduction of curved motion to rectilinear motion, seems to be connected to his assertion mentioned above that lines are described by the "*fluxus* or motion of a point":[40] for according to Fabri, circles (or curves) are "created" by a line "impeded" along the tangents, i.e. they may be said to result from a point creating a line while directing itself along "momentary" tangents to the trajectory. Fabri indeed connects (though not very clearly, it must be admitted) between the notion of *fluxus*, which as stated in Part I he regards as a sort of "process" by which local motion is created,[41] and the direction of motion: "a line of motion," he says, "does not differ from motion itself in a continuous course, or a kind of sliding *fluxus*".[42] In Part I (Section 3.1 above) I have mentioned Paolo Mancosu's claim concerning "the connection between the widespread use of motion in mathematics during the seventeenth century and the emergence and flourishing of the mechanistic viewpoint", listing Fabri among the mathematicians who applied motion in their geometry. Part III has indeed exposed progressive tendencies in Fabri's mechanical thought. It must be emphasized that a satisfactory account of how it relates to Fabri's mathematical thought involves a more detailed research, which must include Fabri's mathematical works. The analysis based on his *Metaphysica*, which discusses Fabri's strange notion of *medium*, and its connection to *fluxus* and impetus (Part I), and the account offered here – based on the *Tractatus* and depicting a strong connection between Fabri's *determinatio* and linearity of impetus, but only a vague link between the concept of *fluxus* and the inherent linearity of motion – seem to me to strongly encourage a more detailed research in this direction, which should include at least his *Opusculum geometricum de linea sinuum et cycloide* (1659) and *Synopsis geometrica* (1669).

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[40] "Severior Geometria, ut omittam Astronomiam, motum supponit, cum ex fluxu seu motu puncti infinitas fere lineas describat" (see Section 3.1, Note 18 above).

[41] The definition (in the beginning of Chapter 3 above, Note 1 above) "motus localis est transitus mobilis e loco in locum continuo fluxu".

[42] "Tertio: linea motus non differt ab ipso motu continuo tractu, seu fluxu quasi labenti" (Fabri 1646, lib. 1, th. 114, scholium, p. 61).

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Chapter 16
Projectile Motion and the Rejection of Superposition

It has been already mentioned (in Chapter 13 above) that although Fabri does give up the medieval question "why does a projectile continue to move?" in favor of the "classical" question "why does a projectile cease to move?", his answer to it is completely non-classical. We shall soon see that while claiming that in the absence of gravity (and air) the projectile would move infinitely along a straight line and with a constant speed, Fabri believes nevertheless – in line with scholastic tradition – that the interaction between the horizontal violent motion and the vertical natural motion of the projectile *necessarily* causes the gradual destruction of the former, even in the case of a horizontal projectile (in which these tendencies are orthogonal). Fabri's theory of projectiles – especially its rejection of superposition – is highly important, and will be discussed here in detail.

The principle of superposition, according to which the overall motion of a projectile may be regarded as a composite of two components which do not interfere with each other, is already foreshadowed in the Aristotelian treatise *Mechanica*, which utilizes this idea to prove the parallelogram rule of velocities, namely that uniform motions along two adjacent sides of a parallelogram join to form a composite motion along its diagonal.[1] Aristotle himself stressed that "lateral motion is not the contrary of upward motion",[2] and implemented the parallelogram rule in his account of "shooting stars", whose motion is caused by superpimposing two components acting together: the sudden condensation of hot vapor, which causes violent motion downwards, and its natural motion upwards: "under these circumstances", explained Aristotle, "an object always moves obliquely".[3] Furthermore, superposition was implicitly employed by Nicole Oresme, to show that the observable fact that an arrow thrown upwards returns to its original place does not prove that the earth is immobile – for if the earth were rotating, the arrow would share that motion and thus would still seem to us as moving along a straight line.[4] However,

[1] *Mechanical Problems*, 1, 848b10–b22, in Aristotle 1936 (this text was probably written by one of Aristotle's students). See also Clagett 1959, p. 94.

[2] *Physics* [Aristotle 1930], 8, 8, 262a12.

[3] *Meteorology* [Aristotle 1931], 1, 4, 342a22–28.

[4] Oresme 1968, lib. 2, ch. 25, pp. 525, 527.

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before Galileo no one has ever applied this principle – so commonly used in modern science – to an inner analysis of projectile motion, i.e. the investigation of the interaction between the intrinsic influences that are involved with this kind of motion (regardless of whether the external environment – namely, the earth – is immobile or rotating).[5] Oresme himself, referring to the quality of impetus which is impressed on the projectile by the projector, claims that "the natural quality of the moving object, its weight, reduces this quality or tension which militates against its natural motion so that the movement slows down and the violence diminishes and finally stops".[6] Oresme thus conveys the view – correctly attributed by Drake also to Buridan before him and Fabri after him – that the impressed impetus and the projectile's weight are "contrary inclinations" that always (even when they are perpendicular) "fight" with each other, an approach which does not allow for superposition.[7]

Following the general scholastic belief (shared by Fabri), that gravity is "an inexhaustible force (*vis infatigabilis*) whose operation can be temporarily hindered but never destroyed" (Maier 1982, p. 111), the inevitable result of such a "fight" would be the gradual diminution of violent motion – in line with Aristotle's important dictum that violent motion is by definition ephemeral.

As Galileo explains in his *Two New Sciences*, thanks to the principle of superposition, the violent motion pushing a projectile does not necessarily "fight" its natural motion; in fact, in the case of horizontal projectiles, these two motions do not interfere at all with each other – contrary to the traditional scholastic view, that violent motion must be gradually diminished (mainly by gravity) as projectile motion advances. In the beginning of the Fourth Day of the *Two New Sciences*, while praising Salviati for his brilliant analysis of projectile motion, Sagredo refers to this important rule:

> It cannot be denied that the reasoning is novel, ingenious, and conclusive, being argued *ex suppositione*; that is, by assuming that the transverse motion is kept always equable, and that the natural downward [motion] likewise maintains its tenor of always accelerating according to the squared ratio of the times; also that such motions, or their speeds, in mixing together do not alter, disturb, or impede one another.[8]

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[5] It was actually Cavalieri who first published, in his *Lo Specchio Ustorio* (1632), a demonstration of the parabolic shape of a projectile's trajectory; however, "it is clear that Cavalieri was convinced he had merely repeated a result achieved by Galileo and known among Galileo's disciples to have been achieved by him" (Damerow et al. 2004, p. 284; see also Koyré 1978, pp. 237–241). It is worth emphasizing that while the "traditional" application of superposition (inspired by the Pseudo-Aristotelian *Mechanical Problems*) involves uniform motions only, a projectile's trajectory has of course a non-uniform component; Torricelli in fact composed uniform motion with motions of higher and higher degrees ($v \propto t^2$, $v \propto t^3$ etc.) to obtain parabolas of higher and higher degrees – cubic, quartic etc. (Boyer 1949, pp. 130–132).

[6] "Et lors la qualité naturelle de la chose meue, si comme est pesanteur, fait appeticier ceste qualité ou redeur qui enclinoit contre le mouvement naturel de la chose, et va le mouvement en retardant et la violence en appetiçant et finablement cesse" (Oresme 1968, lib. 2, ch. 13, p. 417).

[7] In fact, Oresme's theory of projectiles contradicts classical mechanics even more than Buridan's, because Oresme's impetus is not permanent, and also since he opts for an "initial acceleration" of projectiles, thus claiming that after the projectile is thrown it accelerates for a short while and only then starts to decelerate (Clagett 1959, pp. 552–553, 681).

[8] Galilei 1989, p. 222; text in brackets – Drake's.

Descartes, in a famous letter to Mersenne from 11 October 1638, severely criticized Galileo's analysis of free fall, but within this criticism conveyed his acceptance of the basic idea of superposition: "given this", he claimed – referring to Galileo's assumptions of a horizontal constant velocity and vertical constant acceleration (which Descartes rejected) – "it is very easy to conclude that the movement of bodies thrown ought to follow a parabolic line" (Damerow et al. 2004, p. 350). Gassendi also accepted superposition as the correct way of deriving the trajectory of the projectile (Palmerino 2004, p. 148). As will soon be shown, this conclusion – "very easy to conclude" not only by Galileo, Descartes and Gassendi, but also by all their followers – is flatly rejected by Fabri, whose analysis of projectile motion discloses a full and explicit acceptance of the principle of CRM on the one hand, but a decisive rejection of superposition on the other hand.

But it is important to remember that although Galileo and his followers were of course proved to be correct, Galileo clearly lacked a firm concept of CRM and thus was unable to derive rigorously and universally the parabolic trajectory of a projectile. Descartes indeed criticized Galileo for failing to supply an adequate proof for the trajectory of an oblique projectile, and it was only Torricelli who solved this problem, thus becoming the first to exhibit, in this context, the shift from Galileo's Preclassical theory to Classical Mechanics.[9] The fact that Galileo saw fit to invoke motion along a plane in order to justify the conservation of the horizontal velocity (rather than regarding CRM as an independent principle),[10] as well as his insistence – even in his *Two New Sciences* – that the curve described by a hanging chain is also parabolic, and furthermore that the catenary shares a dynamic explanation with the projectile, attest to the non-classical aspect of his mechanical thinking.[11]

16.1 The Basics of Fabri's Projectile Theory

Fabri's analysis of projectile motion appears in book 4 of the *Tractatus*, entitled "On motion mixed from two or many straight lines" (*De motu mixto ex duobus*, *vel pluribus rectiis*). Mixed motion, explains Fabri in the first definition, arises from two impetuses (or more) which are applied to the same body and are determined either along the same line or along different lines; for example, a projectile thrown downwards moves along a single line but in a mixed motion, "for the motion is neither purely natural, nor violent".[12] Now Fabri formulates three hypotheses, i.e. qualitative statements drawn from sensible experiences that are considered entirely valid

[9]Damerow et al. 2004, pp. 251–254, 284–286, 351.

[10]Damerow et al. 2004, pp. 261–262.

[11]Renn et al. 2001, pp. 30, 51, 92–104, 113–126, 131–132. The curve of the catenary is of course not a parabola, but a hyperbolic function which resembles a parabola "if the distance between the two suspension points substantially exceeds the vertical distance between the suspension points and the lowest point of the chain" (ibid., p. 38).

[12]"Motus mixtus est, qui sequitur ex multiplici impetu ad eandem, vel diversas lineas determinato, vel eodem ad diversas… observabis tantum ad motum mixtum sufficere duplicem impetum ad

and suitable to serve as premisses for the subsequent deduction of propositions.[13] The first two hypotheses observe that a body thrown horizontally, as well as a ball dropped from the mast of a moving vessel, will move through curved trajectories.[14] Hypothesis 3 is highly important, and as will be shown plays a crucial role in Fabri's subsequent analysis:

> A horizontal projectile close to the end of its motion strikes less hard than at the beginning, indeed also a projectile thrown downwards at an angle. This hypothesis has been proved a hundred times, and cannot be cast in doubt.[15]

Fabri's third hypothesis, which he regards as valid not only for actual circumstances but also concerning ideal conditions (i.e. in vacuum[16]), seems strange to the twenty-first century reader, who following Galileo's analysis knows that neglecting air resistance even a horizontal projectile (let alone a projectile thrown in a downward inclination) necessarily increases its velocity as it falls, and therefore strikes harder, not less hard, as the motion advances. Fabri – as will soon be shown – is indeed well aware of Galileo's analysis, and rejects it, basing himself on this hypothesis, taken from experience. It should be noted that the trajectories of actual projectiles – even relatively heavy bodies moving with relatively low velocities – are highly influenced by air resistance, so Fabri's third hypothesis is actually reasonable (provided, of course, it is not extrapolated to an environment devoid of air resistance); as A. R. Hall remarks, "experiment, even with slow-moving bodies, at once reveals that projectiles do not move in a parabola" (Hall 1952, p. 96). However, as we shall soon see, unfortunately hypothesis 3 will lead Fabri away from the path to a classical analysis of projectiles, so brilliantly established before him by Galileo and his disciples.

The first theorems describe how two different impetuses, applied to a given object, interact with each other to produce the resultant motion. Fabri refers the reader to theorems 137–142 of the first book, which I have mentioned earlier as containing his "vector analysis" – an essential ingredient of his theory of projectiles. Figure 16.1 presents two cases: in the first case the two impetuses are equal (AB = AD), and in the second case one of them is bigger (AC > AD). As Fabri has explained in theorem 137 of the first book, in each case the resulting motion will be determined – according to the old parallelogram rule of velocities – along the diagonal of the rectangular figure: in the case of AB and AD, along AE; in the case

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eandem lineam determinatam, deorsum, v.g. in mobili proiecto; nec enim est motus pure naturalis, nec etiam violentus, ut constat; igitur mixtus" (Fabri 1646, lib. 4, def. 1, pp. 153–154).

[13] For Fabri's notion of "hypothesis" see Chapter 2 above.

[14] Fabri 1646, lib. 4, hyps. 1–2, p. 154.

[15] "Proiectum per horizontalem sub finem motus minus ferit quam initio, imo & proiectum per inclinatam deorsum; haec hypothesis centies probata fuit; nec in dubium revocari potest" (Fabri 1646, lib. 4, hyp. 3, p. 154). According to Fabri, the only case in which the projectile is accelerated is a purely vertical downward throw (or fall).

[16] When Fabri later discusses – and rejects – the possibility that it is air resistance which is responsible for the decrease in velocity, he claims that the effect of air resistance is so marginal that in vacuum the projectile would behave in the same way (see Section 16.1, Note 36 below).

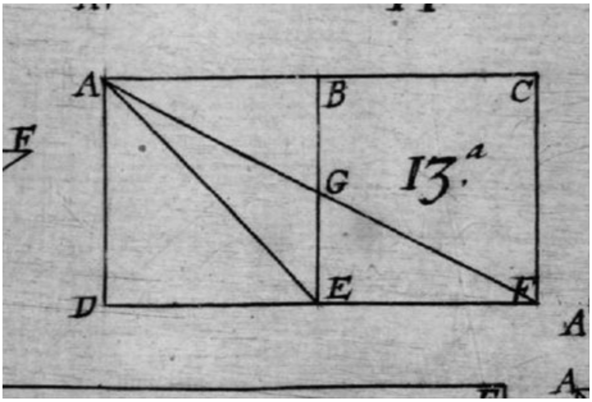

Fig. 16.1 Interaction of two impetuses (Fabri 1646, tabula I)

of AC and AD, along AF. However, Fabri's analysis does not end here. Theorems 141 and 142 explain that two impetuses determined along different lines "fight each other *pro rata*" (*pugnant pro rata*), i.e. according to the angles between them, and that the closer they are to being opposite, the more impetus is destroyed (following the "vector addition"), while the closer they are to coalescing (*ad coeuntes*), the less impetus is destroyed.[17] Theorem 6 in the fourth book claims therefore that "hence some impetus is destroyed, according to theorems 141 and 142 from the first book, and this occurs *pro rata*, so that nothing will be in vain (*frustra*)".[18] "Hence", states theorem 7, which refers to the two "vector additions" described in Fig. 16.1, "the portion of each destroyed impetus can be determined. For instance, if they [i.e. the impetuses] are equal, the portion drawn away from them in equal times is the difference between the diagonal and the sum of DA and AB, which is clear; if the impetuses are unequal, the destroyed portion will always be the difference between the diagonal – e.g. AF – and the sum of AC and AD."[19]

Contrary to what the reader might assume, the term "destroyed portion" does not refer to the (trivial) fact that the diagonal of a rectangle (or square) is always smaller than the sum of its two adjacent sides. The meaning of this "destroyed" impetus, constituting Fabri's "destruction mechanism" (or *frustra* mechanism) becomes clear only when Fabri elaborates his theory of oblique projectiles, in which this *frustra* mechanism is used to determine the motion of a projectile in consecutive

[17] Fabri 1646, lib. 1, th. 137, p. 66 and ths. 141–142, p. 67. When the impetuses coincide, i.e. point to the same direction, no impetus is destroyed.

[18] "Hinc destruitur aliquid impetus per Th. 141. & 142 l.1, idque pro rata, ne aliquid sit frustra" (Fabri 1646, lib. 4, th. 6, p. 155).

[19] "Hinc determinari potest portio utriusque impetus destructi, v.g. si sint aequales, portio detracta utrique aequalibus temporibus est differentia diagonalis & compositae ex DA, AB, quod clarum est; si vero impetus sint inaequales, portio destructa erit semper differentia diagonalis, v.g. AF & compositae ex AC.AD" (Fabri 1646, lib. 4, th. 7, p. 155).

iterations. In each of these iterations, Fabri calculates the resultant motion by combining the impetus along the projectile's trajectory with the innate natural impetus (i.e. heaviness), according to this *frustra* mechanism. Fabri prefers to fully explain the working of this "destruction mechanism" only when he specifically deals with oblique projectiles, and so shall we.

In theorem 21 Fabri begins to discuss specifically a horizontal projectile, which he sees as a "mixed motion" resulting from two impetuses: an innate impetus downwards, and an impressed horizontal one.[20] In the following theorems Fabri wishes to characterize more accurately these two components of horizontal projectile motion: is each of them constant (*aequabilis*), accelerated (*acceleratus*) or decelerated (*retardatus*)? Fabri correctly remarks that all in all 9 ($=3^2$) possibilities (*combinationes*) exist, and his aim is to reject the eight wrong ones and thus reveal the true *combinatio*.[21] Most of the combinations are rejected by him immediately, especially the six that do not involve accelerated natural motion: for he has already shown (in book II, *De motu naturali deorsum*) that natural motion downwards cannot be constant,[22] while the assumption that it is decelerated is entirely out of the question, since "innate impetus is never destroyed".[23] The assumption that violent motion is accelerated is also *ipso facto* rejected, for "there is no cause by which violent [motion] could be accelerated";[24] it is worth adding that Fabri thus rejects Oresme's ascription of an "initial acceleration" to projectiles (see Note 7 above). We are left then with only two viable options, which are indeed thoroughly discussed by Fabri: that horizontal projectile motion consists of accelerated natural motion and constant violent motion, and that it is a result of accelerated natural motion and decelerated violent motion. Fabri's analysis aims to reject the first of these options – which is of course none other than that of Galileo (i.e. the classical solution) – and thus substantiate the validity of the second one. Fabri's evaluation (and ultimate rejection) of Galileo's view is of course highly important and worth describing.

Fabri first mentions Galileo's solution to the problem of projectile motion already in theorem 17, in which Fabri declares that a mixed motion which consists of constant violent motion and accelerated natural motion occurs along a curved line (*per lineam curvam*).[25] This curve, explains Fabri in theorem 18, "is a parabola, as Galileo himself so often insinuated, and which anyone – even the quite ignorant in geometry – would understand; on which I shall not dwell too long, especially since there exists no motion which consists of constant [violent] and naturally accelerated

[20] Fabri 1646, lib. 4, th. 21, p. 159.

[21] Fabri 1646, lib. 4, th. 30, p. 161.

[22] Fabri 1646, lib. 4, th. 24, p. 159; see also Fabri 1646, lib. 2, th. 59, p. 95.

[23] ". . . quia numquam destruitur impetus innatus" (Fabri 1646, lib. 4, th. 25, p. 160).

[24] ". . . nulla est causa, a qua violentus possit accelerari" (Fabri 1646, lib. 4, th. 23, p. 159).

[25] Fabri 1646, lib. 4, th. 17, p. 158.

[motion], as we shall prove below".[26] Theorem 19 briefly discusses the characteristics of the parabola, and explains that if the horizontal component of the overall distance is divided into 4 equal parts (AB=BC=CD=DE in Fig. 16.2), the vertical

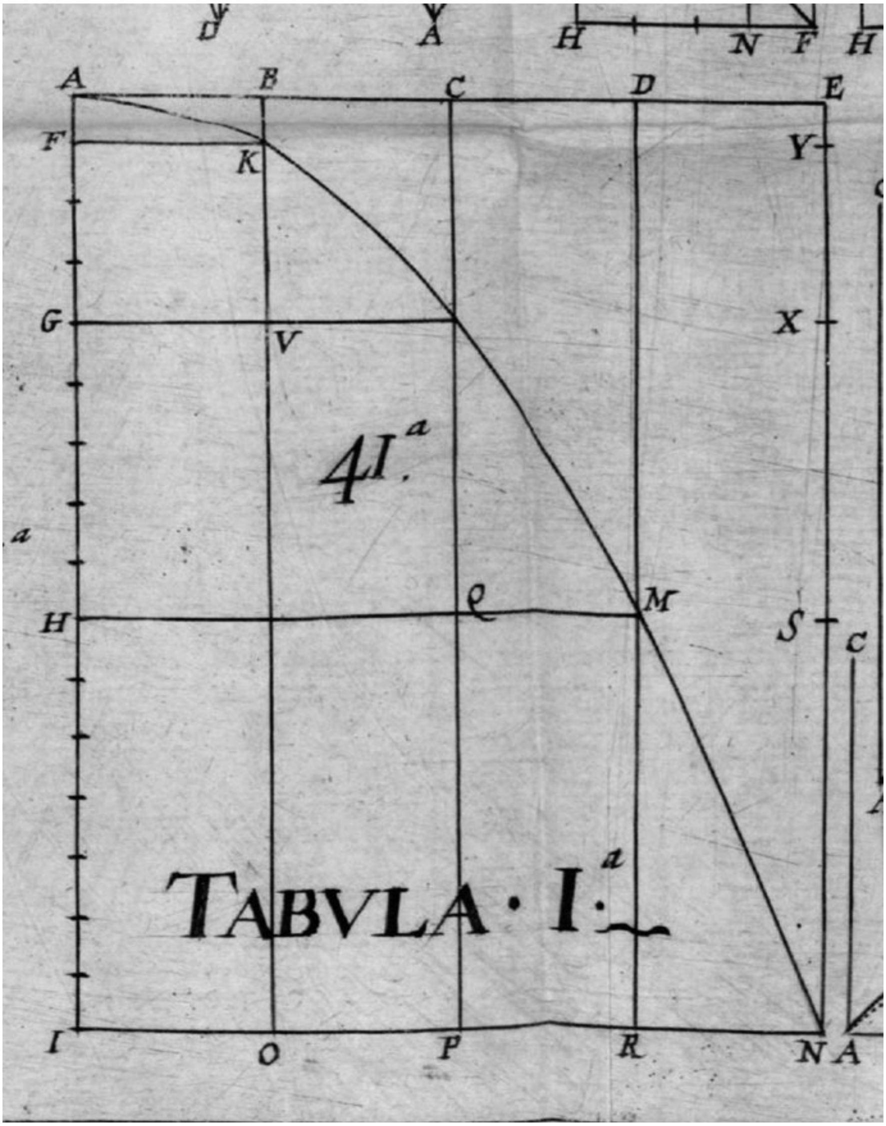

Fig. 16.2 Fabri's depiction of Galileo's solution (Fabri 1646, tabula I)

[26]"Haec linea est Parabola; quod ipse Galileus toties insinuavit, & quivis etiam rudior Geometra intelliget; in quo diutius non haereo, praesertim cum nullus sit motus, qui constet ex aequabili, & naturaliter accelerato, ut demonstrabimus infra" (Fabri 1646, lib. 4, th. 18, p. 158).

component will be composed of four parts that behave like the series 1, 3, 5, 7 (AF, FG, GH, HI), while the overall vertical distances behave of course like the accumulated sums, i.e. the series 1, 4, 9, 16 (AF, AG, AH, AI).

However, Galileo's view is presented only in order to be rejected, and thus pave the way for Fabri's preferred option. Theorem 26 declares – *pace* Galileo – that horizontal projectile motion

> is not a mixture of natural accelerated and violent constant [motion]; it is proved firstly since [in that case] close to the end of motion the impetus would be greater; since nothing would be taken from the violent [impetus], while much would be added to the natural [impetus]; therefore it [i.e. the total impetus] would be greater, therefore the strike would be greater, against hypothesis 3.[27]

Now we can appreciate the importance of hypothesis 3, described a few pages above (see Note 15), which claims that "a horizontal projectile close to the end of its motion strikes less hard than at the beginning": Fabri uses this (allegedly) irrefutable observation to invalidate Galileo's theory, since if we assume that the horizontal velocity does not change during the projectile's motion, while the vertical component must accelerate, then hypothesis 3 is immediately violated. Fabri's following two arguments invoke the "destruction calculus" of impetuses mentioned above (and to be fully explained below): he claims that if under the assumption of two constant impetuses (natural and violent) this "destruction calculus" would inevitably lead us to the conclusion that some impetus is destroyed, then "all the more so" (*potiori iure*) if we take into account the fact that natural motion is accelerated.[28] Fabri means that if we deduce – according to hypothesis 3 – that the violent impetus must be destroyed, then this conclusion should be *potiori iure* valid after we realize that natural motion accelerates, and therefore contributes to the overall velocity (while hypothesis 3 demands that the overall velocity decreases).

As is well known, Galileo's (many) adversaries simply claimed – not without justification – that the observed path of a projectile was *not* a parabola, while the Galileans responded that this analysis neglects (and is justified in neglecting) air resistance. Torricelli, for instance, in his *De motu proiectorum* (1644), insisted that the Galilean analysis "was purely theoretical, that it explained not what is observed to happen but what would happen under specified conditions" – i.e. in a vacuum – "and that his purpose was the mathematical consideration of such hypothetical motion" (Hall 1952, pp. 96–97).

Fabri's remainder of theorem 26 rejects the claim (supported by the Galileans, and also of course by classical physics) that air resistance should be held responsible for the conspicuous difference between theory (geometrically defined parabola) and practice (observed curved trajectory):

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27 "Non est mixtus ex naturali accelerato & violento aequabili; demonstratur, primo, quia sub finem motus esset maior impetus; quippe nihil detraheretur violento, sed multum accederet naturali; igitur esset maior, igitur esset maior ictus contra hyp. 3" (Fabri 1646, lib. 4, th. 26, p. 160).

28 ". . . secundo, quotiescunque sunt duo impetus in eodem mobili ad diversas lineas determinati, aliquid illorum destruitur per Th. 141.l.1. tertio si esset uterque aequabilis, aliquid destrueretur per Theorema 6, igitur potiori iure, si impetus naturalis crescat" (Fabri 1646, lib. 4, th. 26, p. 160).

> Someone would perhaps claim that the impetus is destroyed by air, but it was already answered that from this a small amount is diminished, for the air never destroys in a heavy body as much impetus as natural [impetus] is produced if it is accelerated; otherwise motion [i.e. velocity] downwards would not increase, contrary to experience.[29]

Already in book 2 Fabri has emphasized the negligible effect of air resistance on falling bodies, which in his opinion impedes "such a trifle" (*tantillum*) from natural acceleration.[30] Fabri's rather strange assumption, that if the influence of air resistance on a falling body were not very small it would not be accelerated, leads him to formulate (in theorem 28) a totally erroneous argument against the Galileans:

> Hence you will reject Galileo, who in the *Dialogues* always supposed these things, but never proved – or could prove them. This is also supposed by many of Galileo's followers, who believe that impetus could be destroyed only by the resistance of the medium; but I ask them, what kind of a medium would destroy a part of the impetus in a mixed motion? For the line of a mixed motion is not equal to those from which it somehow results.[31]

Fabri is convinced then that while the horizontal component of a projectile is substantially reduced – for the resultant of the components is indeed "not equal" to them (it is smaller than their scalar sum) – the acceleration downwards remains almost totally unaffected. It is therefore a mistake, he deduces, to account for the obvious horizontal reduction of velocity (clearly manifested by hypothesis 3) using air resistance. Interestingly, Fabri launches a similarly formulated attack against the Galileans in book III (*De motu violento sursum perpendiculariter*), calling the reader to hence reject "Galileo and other followers of him who think that impetus impressed on a body is destroyed only by air".[32] Fabri, while claiming (correctly of course) that air resistance cannot be seen as the main reason for the deceleration of a body projected vertically upwards – concluding that the main factor must be innate impetus (i.e. gravity), which is diametrically opposed to the impressed violent impetus and therefore "fights" (*pugnat*) it *pro rata*[33] – strangely ascribes to the Galileans the claim that air resistance is the principal cause of deceleration in this case. Fabri must have "extrapolated" this Galilean assertion – indeed valid for horizontal (or downwards inclining) projectiles – to ascending projectiles, and thus misinterpreted the Galilean theory; more importantly, Fabri was absolutely convinced that if innate

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[29] "Diceret forte aliquis impetum destrui ab aere, sed iam supra responsum est modicum inde imminui; nec enim unquam aer in corpore gravi destruit tantum impetus, quantum producitur naturalis si sit acceleratus; alioquin motus deorsum non cresceret contra experientiam" (Fabri 1646, lib. 4, th. 26, p. 160).

[30] Fabri 1646, lib. 2, th. 61, p. 96.

[31] "Hinc reiicies Galileum, qui in dialogis haec semper supposuit, sed nunquam probavit, nec probare unquam potuit; hoc etiam supponunt multi Galilei sectatores, qui censent impetum nunquam destrui nisi a resistentia medii; sed quaero ab illis quodnam medium destruat partem impetus in motu mixto; nec enim linea motus mixti adaequat duas alias ex quibus quasi resultat" (Fabri 1646, lib. 4, th. 28, p. 160).

[32] "Hinc reiicies Galileum, & alios eius sectatores qui volunt impetum corpori impressum destrui tantum ab aere" (Fabri 1646, lib. 3, th. 45, p. 144).

[33] Fabri 1646, lib. 3, th. 20, p. 138.

impetus was responsible for the deceleration of ascending projectiles, why not suppose it also causes the deceleration of horizontal projectiles, and even downward inclining ones?[34] This is indeed how Fabri concludes his argument (in theorem 28) against the Galileans, regarding horizontal projectiles:

> Certainly this [i.e. the destruction of impetus] cannot be explained by anything else, save by saying that impetus is destroyed by another impetus, in the same manner we have often mentioned, that is in order not be in vain (*frustra*). Therefore violent impetus is destroyed by innate [impetus].[35]

Before returning to Fabri's actual theory of projectiles, it is worth examining another remark he formulates concerning air resistance, which exemplifies his unique position among other contemporary adversaries to the Galilean theory. In theorem 36 Fabri objects again to the assertion that it is the medium which is responsible for the deceleration of horizontal projectiles, "since the air does not resist violent motion more than [it resists] natural [motion]; but as every one will admit, what is subtracted by air from a heavy body – e.g. a leaden ball – is insensible; therefore the same should be claimed about violent and mixed motion, hence this very thing would also occur in a vacuum".[36]

Again, Fabri's main point is that because air resistance (allegedly) almost has no effect on natural impetus, we should not suppose (as the Galileans did) that air has any substantial effect on violent or mixed motion. Fabri's conclusion from this reasoning[37] – that therefore the behavior in the void would be exactly the same – is entirely consistent with his general "inertial framework", expressed also in his assertion, concerning the analysis of free fall, that "if the heavy body were to descend in a vacuum, the abovementioned proportions would be preserved very accurately".[38] This view was apparently rather unique among the main contemporary anti-Galilean theorists, heavily influenced by the "plenum paradigm", be it the old one (Aristotle) or the new one (Descartes). As Hall explains – regarding specifically projectile motion – "Galilean dynamics denied two important philosophic assumptions: the first, that air resistance has important effects on the motion of heavy bodies, had been accepted by Aristotle and even widened by the impetus school; the second, that the universe is a plenum, had been almost unchallenged since late classical times and

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[34] With the exception of a projectile thrown vertically downwards, where the natural and the violent impetuses are directed along the same line and therefore do not "fight" each other.

[35] ". . . certe hoc non potest explicari cum infinitis fere aliis, nisi dicatur impetum destrui ab alio impetu, eo modo quo saepe diximus, hoc est ne sit frustra; igitur impetus violentus destruitur ab innato" (Fabri 1646, lib. 4, th. 28, p. 160).

[36] "Hinc ratio clara cur sit minor ictus in fine huius motus; quia scilicet est minus impetus, quia plus detractum est quam additum; nec est quod tribuant hanc retardationem medio; quippe aer non plus resistit motui violento quam naturali; sed id quod detrahitur ab aere corpori gravi, v. g. pilae plumbeae est insensibile, ut fatentur omnes; igitur idem dicendum est de motu violento & mixto, hinc hoc ipsum etiam fieret in vacuo" (Fabri 1646, lib. 4, th. 36, p. 162).

[37] Which perhaps could be seen (certainly in retrospect) as the weakest part of Fabri's argumentation.

[38] Fabri's theorem 13, explained in Part II, Chapter 8 above.

was revived in the philosophy of Descartes" (Hall 1952, p. 103). Indeed Galileo's critics, especially the French philosophers who were grouped around Mersenne, doubted the validity of Galileo's analysis, explicitly confined to motion in the void: "Neither Mersenne, Fermat, Roberval or Descartes", remarks Hall, "believed that there could be entire truth in theorems dependent on such an extreme simplification of the normal world of experience" (ibid., p. 106). Descartes, for example, within his famous 1638 critique of the *Two New Sciences*, complained against Galileo that "everything he says about the speeds of bodies descending in the void, etc, is built without foundation, for first he should have determined what gravity (*pesanteur*) is, and if he had known the truth, he would have known that it is nothing in the void" (Damerow et al. 2004, p. 350). It is indeed not easy to reconcile the "inertial framework" – which could be considered as shared by Galileo's disciples and Fabri, who all assume that gravity (or innate impetus) is a kind of a force (or *virtus*) that can act on a particle moving in an environment devoid of air – with Descartes' plenum universe of vortices, in which the eternal motion of particles is considered as the very reason for gravity in the first place. Fabri, objecting to Galileo's analysis from his own (wrong) considerations, nevertheless displays no influence whatsoever of any "plenum paradigm": neither Aristotle's, nor Descartes'.

Before presenting in detail his analysis of horizontal projectiles, Fabri sees fit to explain another important principle, concerning the natural acceleration involved in this phenomenon. The motion of a horizontal projectile, remarks Fabri in theorem 29, "is not composed of natural acceleration in the same way in which it is accelerated downwards vertically and from violent decelerated" motion. If such were the case, then the natural impetus could increase exactly as the violent impetus decreases, perhaps even more; therefore the total impetus would be equal or bigger, hence also the strike – "contrary to hypothesis 3".[39] In order to guarantee the validity of hypothesis 3 therefore, it is not enough for Fabri that violent impetus is necessarily and continually diminished (even without air resistance); he is anxious to "hamper" natural acceleration as well, because he fears that the accumulation of natural impetus might compensate for the loss of violent motion (or even exceed it), and thus hypothesis 3 might be violated. Fabri's following statement, that "natural motion is impeded by violent impetus no less than by an inclined plane"[40] exemplifies the total absence of superposition in his thinking: not only does innate impetus necessarily inhibit violent motion, but also violent impetus hinders natural impetus (i.e. acquired natural impetus, not innate impetus, which of course is never destroyed). Fabri concludes that the motion of a horizontal projectile "is composed of decelerated violent [motion] and accelerated natural [motion], indeed not in the way in which it is accelerated vertically, but rather in the manner in which it is

[39]"Non est mixtus ex naturali accelerato eo modo quo acceleratur deorsum per lineam perpendicularem & ex violento retardato: Probatur, si ita est, tantum additur naturali, quantum detrahitur violento, imo plus; igitur semper est in eo mobili aequalis vel maior impetus; igitur aequalis est semper, vel maior ictus contra hyp. 3" (Fabri 1646, lib. 4, th. 29, p. 160).

[40]"... adde quod non minus impeditur ab impetu violento naturalis motus, quam ab inclinato plano".

accelerated along an inclined plane, which is changed here in single instants".[41] It will soon be shown how Fabri implements this "inhibition device" of natural motion, which cooperates together with the "destruction mechanism" (responsible for diminishing violent motion) to absolutely guarantee that hypothesis 3 is not violated.

16.2 Trajectories of Projectiles: The *frustra* Mechanism

Having characterized in principle the motion of horizontal projectile, while rejecting the Galilean view concerning the role of air resistance in projectile motion, Fabri moves on to a detailed account of the actual curved trajectory which results from the interaction between natural impetus and violent impetus. Theorem 37 simply claims that "natural impetus participates in this motion", otherwise the projectile would move along a straight line.[42] Theorem 38 is more specific, and highly important in the context of Part III:

> If natural impetus did not participate in this motion, the projectile would obviously move along a straight horizontal line with constant motion; supposing that it would not be retarded horizontally, it would move in the same way as it would move vertically upwards [again, if natural impetus did not participate in the motion].[43]

This is a very clear manifestation of a principle which we already know to be part and parcel of Fabri's physical thinking: CRM; he even states it as an obvious fact ("*ut constat*"), and this might indicate that Aristotelian physicists were less adamant in rejecting this important principle than modern historians would generally suppose. Be that as it may, Fabri now finally discloses in detail his analysis of projectile motion, which results in a trajectory which is similar to Galileo's parabola, though not identical to it (see Fig. 16.3).

It is important to remark that Fabri's proposed trajectory is curved all along – and thus does not contain any rectilinear component, contrary to Buridan's claim, that towards the end of the projectile's motion its gravity totally "wins out" over the original violent impetus and "moves the stone down to its natural place".[44] In fact, Fabri

[41]"Itaque motus praedictus mixtus est ex violento retardato & naturali accelerato, non eo quidem modo quo acceleratur in perpendiculari, sed eo quo acceleratur in plano inclinato, quod hic singulis instantibus mutatur" (Fabri 1646, lib. 4, th. 30, p. 161).

[42]"Impetus naturalis concurrit ad hunc motum; probatur, quia alioquin esset rectus" (Fabri 1646, lib. 4, th. 37, p. 162).

[43]"Si impetus naturalis non concurreret ad hunc motum, proiectum moveretur per lineam horizontalem rectam, ut constat, motu aequabili; posito quod non retardaretur in horizontali, eodem modo moveretur quo in verticali sursum" (Fabri 1646, lib. 4, th. 38, p. 162).

[44]Clagett 1959, p. 535. The traditional view still appeared even in the writings of Nicolo Tartaglia (1558) and Diego Ufano (1628), though Tartaglia was actually aware of the continuous curvature of the trajectory. On this peculiar situation, see Büttner et al. 2003, pp. 13–16.

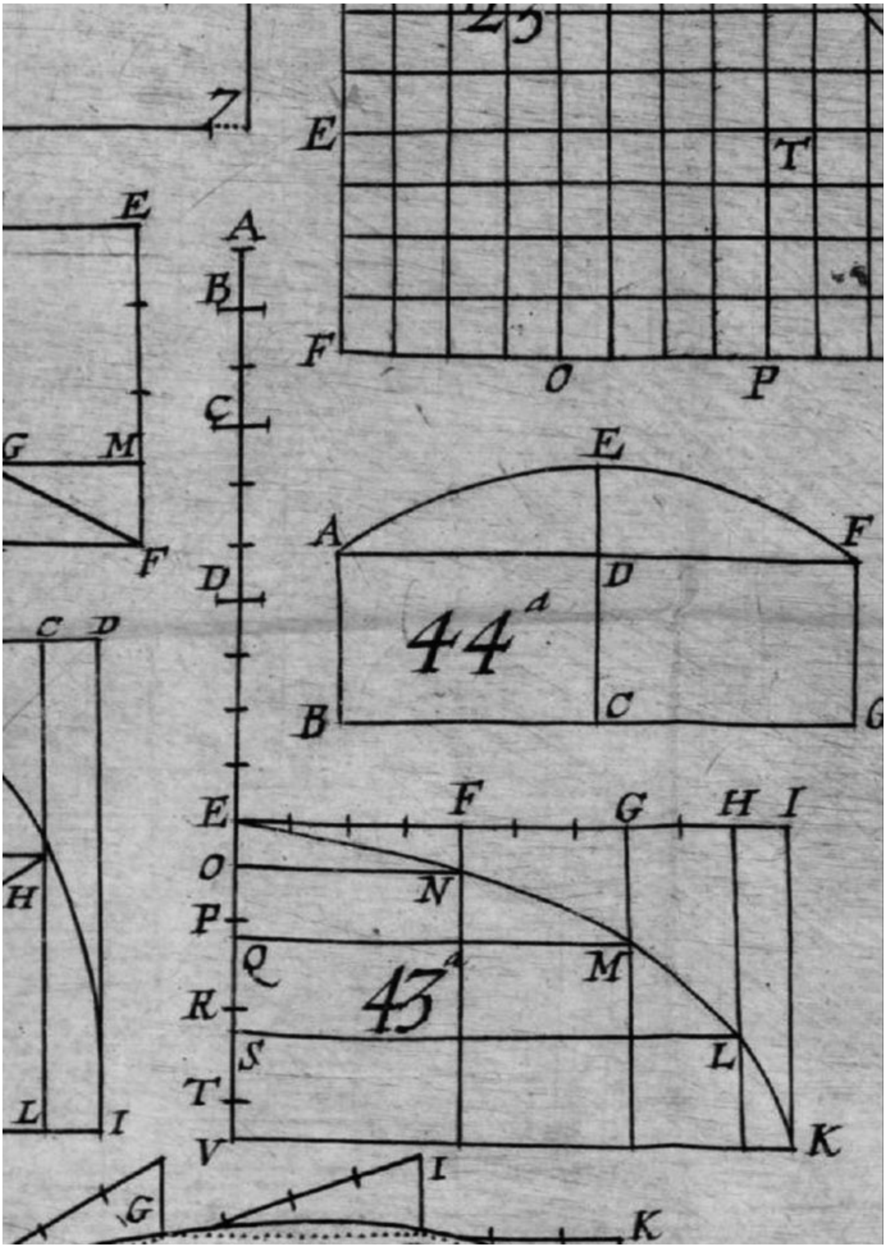

Fig. 16.3 Trajectory of a horizontal projectile (figure 43; Fabri 1646, tabula I)

sees fit to rebuke the Spanish artillery expert Diego Ufano for supposing that a projectile thrown upwards at an angle starts its motion with a straight line.[45] In any case, thanks to Fabri's earlier elaborate discussion (essentially repeated in theorem 39) we can understand exactly what is going on in Fig. 16.3. The lack of superposition is obvious in the gradual decrease of the horizontal distance acquired in consecutive instants (HI<GH<FG<EF). The changing rate of the downward acceleration is also easy to recognize: while EO is the vertical distance acquired within the first period of time, Fabri explains that the distance acquired in the second period of time is OQ, which is bigger than EO by PQ, i.e. OQ = OP + PQ = EO + PQ. According to his earlier statement, that the acceleration downwards behaves not like vertical acceleration but like that along an inclined plane, Fabri decides that PQ depends on the declination of the right-angled triangle, i.e. the angle ENO. Similarly, RS – the addition to the distance in the third period of time – depends on the steeper right-angled triangle whose hypotenuse is MN, whereas TV – the addition to the distance in the fourth period of time – depends on the even steeper right-angled triangle whose hypotenuse is ML. The downward acceleration then is not constant, but starts at close to zero and only at the end of the motion does it approach its maximum value (PQ<RS<TV). Fabri emphasizes again that the natural impetus must increase at a slower rate than the decrease of the violent impetus.[46]

The trajectory described by Fabri in Fig. 16.3 is fully compatible with his earlier explanations and arguments; however, it is not clear how he came up with the horizontal component of the projectile: judging by the figure, Fabri assumes that the horizontal distances diminish in a constant ratio, and this choice (unexplained in theorem 39) seems arbitrary. In theorem 41 Fabri admits that he supposes here that violent impetus "always decreases in the same proportion", but soon adds that this is only for the sake of example (*exempli gratia tantum*).[47] Fabri's full blown theory of projectiles does not assume a constant horizontal deceleration, but rather implements the *frustra* mechanism for destroying impetus mentioned (but not fully explained) in Section 16.1 above.

Fabri divides the motion of an oblique projectile into two parts: the ascending component, and the descending one. The ascending part is composed of a constant natural motion – for innate impetus never decreases, while it certainly does not increase in an ascending motion – and decelerated violent motion;[48] the descending part, claims Fabri, is identical to the motion of a horizontal projectile.[49] Now Fabri analyzes the motion of an oblique projectile first under the assumption that the violent impetus decreases like an arithmetical series,[50] and then assuming that

[45] Fabri 1646, lib. 4, th. 59, cor. 9, p. 170.

[46] Fabri 1646, lib. 4, th. 39, pp. 162–163.

[47] Fabri 1646, lib. 4, th. 41, p. 163.

[48] Fabri 1646, lib. 4, th. 52, p. 166.

[49] Fabri 1646, lib. 4, th. 53, p. 166.

[50] Fabri 1646, lib. 4, th. 55, pp. 166–167 (the result is Fig. 47 in Fig. 16.4 below).

it decreases according to the series of odd numbers.[51] At this point he remarks that "we have not yet determined the proportion by which violent impetus is destroyed in a mixed motion, which nevertheless can be inferred from what has been said above; since it is destroyed *pro rata*, i.e. in the proportion by which the line of a mixed motion is less than the line composed of both".[52]

As we recall, theorem 7 claimed that while combining two impetuses – say AC and AD in Fig. 16.1 – the amount of the destroyed impetus will be the difference between the diagonal (AF) and the sum of AC and AD, i.e. the difference will be AF – (AC + AD). Watching figures 48 and 49 below (in Fig. 16.4), we can now understand the working of Fabri's *frustra* mechanism, and the exact meaning of the term "destroyed impetus". Figure 49 describes the consecutive iterations that constitute the projectile's trajectory: first, the initial impetus AD is combined with

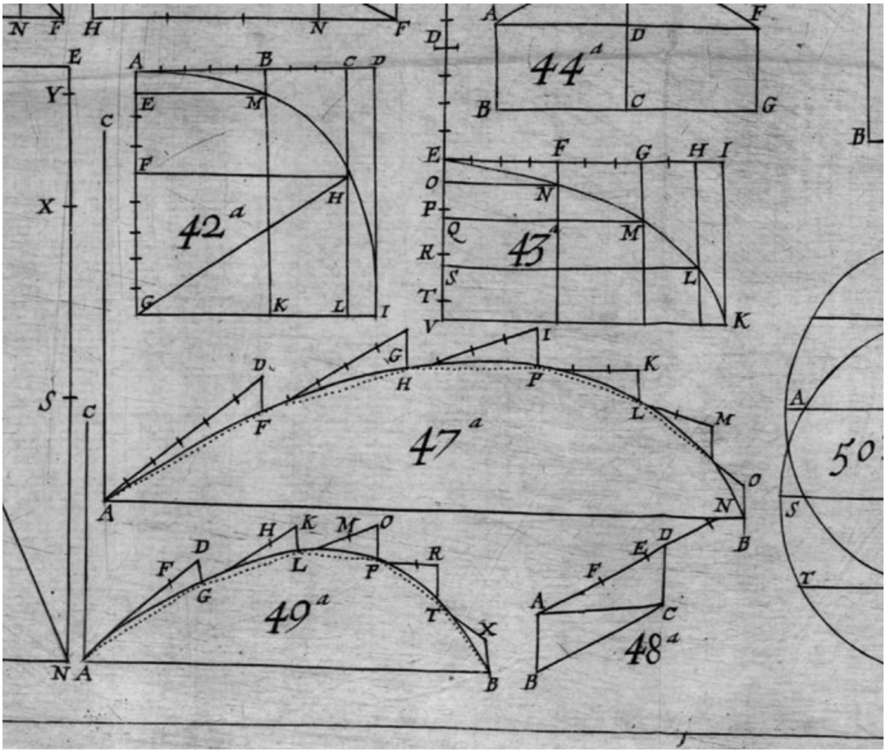

Fig. 16.4 Analysis of an oblique projectile (figures 47–49; Fabri 1646, tabula I)

[51] Fabri 1646, lib. 4, th. 56, p. 166.

[52] "Observabis nondum esse a nobis determinatam proportionem illam, in qua destruitur impetus violentus in motu mixto, quae tamen ex dictis supra potest colligi; quippe destruitur pro rata, idest qua proportione linea motus mixti est minor linea composita ex utroque" (Fabri 1646, lib. 4, th. 56, scholium, p. 167).

the natural impetus (DG), to form the second "trajectoral" impetus (GK), which is in turn combined with natural impetus (KL) to form the new impetus (LO) and so on. The point is that in each iteration, the resultant (i.e. the "trajectoral" impetus of the next iteration[53]) is not the "standard" resultant – i.e. the vector sum of the two impetuses (e.g. AG, the vector sum of AD and DG, or GL, the vector sum of GK and KL) – but rather it is smaller than the "standard" resultant (GK < AG, LO < GL etc.); and the amount by which it is smaller than the "standard" resultant constitutes what Fabri defines as the "destroyed impetus". Diagram 48 illustrates this point, and contains the crux of Fabri's *frustra* mechanism. In his words,

> The violent impetus is destroyed *pro rata*, i.e. by the proportion in which it is *frustra*.[54] Let there be [diagram 48] an impetus AD inclined upwards, and another perpendicular one, AB, inclined downwards [natural impetus]; no doubt the motion will be directed towards AC [the "standard" resultant]; therefore the motions, or rather the impetuses, AB and AD concur along AC; therefore the impetus has to be destroyed in the proportion by which AC [the "standard" resultant] is smaller than AN, i.e. the sum of AD and DC; since impetus AB could not be destroyed,[55] all of the destroyed amount will be subtracted from AD; therefore DF is assumed, namely the difference between AC and AN [i.e. DF = AC – AN]; the destroyed impetus behaves in relation to impetus AD as DF is to AD, and in relation to the residual impetus from AD,[56] as DF to FA [FA = AD – DF], which all agree to theorem 7.[57]

[53] Judging from Fig. 49 (in Fig. 16.4), it seems that each of the "trajectoral" impetuses is not aligned along the tangents to the curve, despite his general reduction of motions to linear tangential motions described above (Section 15.2). In any case, Fabri – who does not decompose the trajectory into a vertical (accelerating/decelerating) component and a horizontal (uniform) one – is indeed still far from classical mechanics.

[54] It is "in vain" because, owing to the fact that the diagonal is always smaller then the sum of the components (i.e. the two sides), it is – as it were – "not needed". The only case in which no amount is *frustra* occurs when the projecting impetus and the natural impetus are aligned in the same direction, i.e. when an object is thrown perpendicularly downwards (see Note 17 above); in any other case the "destruction mechanism" operates to continuously diminish the "trajectoral" impetus (hence Fabri's hypothesis 3).

[55] Again, natural innate impetus can never diminish (see Chapter 8 above), so the *frustra* mechanism can never be applied to it; in the descending part, the natural impetus of course increases, by the accumulation of acquired impetus (OP < RT < XB in diagram 49).

[56] Fabri means here a relation of arithmetical difference, not geometrical proportion.

[57] "Destruitur impetus violentus pro rata, id est, qua proportione est frustra; v.g. sit impetus per AD inclinatam sursum, & alius per AB perpendicularem deorsum; haud dubie motus erit per AC; igitur concurrunt ad motum AC motus AB & AD, vel potius impetus; igitur debet destrui impetus in ea proportione, in qua AC est minor AN, id est composita ex AD, DC; quod impetus AB non possit destrui, totum id quod destruetur detrahetur impetui AD; igitur assumatur DF scilicet differentia AC, & AN; impetus destructus ita se habet ad impetum AD, ut DF ad AD, & ad residuum impetum ex AD, ut DF ad FA, quae omnia constant ex Th. 7" (Fabri 1646, lib. 4, th. 59, p. 168; I have corrected "G" in the original text, a letter which does not appear at all in diagram 48, to "N" – the obvious meaning. This error is probably a typo or a result of an incompatibility between the original text and diagram 48). It should be noted that David Lukens has already explained (in too little detail though) Fabri's implementation of the *frustra* mechanism to projectiles (Lukens 1979, p. 227).

In other words, in accordance with theorem 7, Fabri defines DF as the difference between the "standard" resultant AC and the sum AD + DC, and claims that this amount should be subtracted from the initial impetus to obtain AF, the "residual impetus from AD" (*residuus impetus ex AD*). As Fig. 49 (and the remainder of theorem 59) clarify, this "residual impetus" AF is the starting point of the new iteration. Thus we obtain, for the second iteration, GK = AF = AD – DF; HK is equal to the difference between the sum GK + KL and GL, hence (for the third iteration) LO = GK – HK, and so on.[58]

The descending part is more complicated, since the vertical component, i.e. the natural impetus, is no longer constant but is increased in a non-constant and ever-growing acceleration (according to the "local" inclination, as explained before). As Fabri emphasizes, the result is indeed – as experience tells us – a non-parabolic trajectory, in which the horizontal component is relatively quickly destroyed, and in which (unlike Galileo's parabola) the ascending arc is bigger than the descending arc.[59] "Hence", declares Fabri in corollary 8 of theorem 59, "I reject Galileo, who without any physical justification claimed that both [i.e. the ascending and the descending arcs] are equal, which nevertheless disagrees with all experiences, and even children who play with a discus can see that the arc of its descent is by far smaller". Fabri now neatly summarizes the difference between his view and Galileo's by claiming that the parabola cannot be used to describe projectile motion, because it assumes two false principles: "the constancy of violent motion [i.e. velocity] and [that] of natural acceleration, in the same way which occurs in vertical [acceleration]".[60]

Fabri has finally disclosed his full view regarding impetus destruction and projectile motion – only hinted at in theorems 137–142 of the first book and theorem 7 of the fourth book – along with his total rejection of Galileo's principle of superposition. Instead of relying (like Galileo and classical physics) on air resistance to explain the difference between the observed trajectory of projectiles and the

[58]"Sit ergo AC Fig. 49 perpendicularis sursum, AD inclinata, AB horizontalis; sit impetus violentus respondens AD, & naturalis DG, ducatur AGK, ex AD detrahatur DF, id est differentia AG & compositae ex AD, DG, superest AF, cui assumitur aequalis GK, ex qua detrahitur KH, id est differentia GL, & compositae ex GK, KL, superest GH, cui LO accipitur aequalis, cui detrahitur OM, id est differentia LP & compositae ex LO, OP, superest ML, cui aequalis accipitur PR, atque ita deinceps" (Fabri 1646, lib. 4, th. 59, p. 168).

[59]Of course, the ever-increasing natural impetus in the descending part renders the horizontal distance traversed shorter than in the ascending part (in which the natural impetus does not increase). Fabri's *frustra* mechanism replaces the Galilean (and the classical) "destruction mechanism", namely air resistance, as the explanation for the quick destruction of the horizontal component of an actual projectile. Fabri then is "wrong" from an anachronistic point of view but non inconsistent.

[60]"Hinc reiicio Galileum qui nulla prorsus fultus ratione physica vult utrumque esse aequalem, quod tamen omnibus experimentis repugnat, & ipsi etiam pueri, qui disco ludunt observare possunt arcum descensus sui disci esse longe minorem, nec est quod ad suam Parabolam confugiat, quae duo falsa supponit principia, scilicet aequabilitatem motus violenti, & accelerationem naturalis eo scilicet modo quo fieret in perpendiculari" (Fabri 1646, lib. 4, th. 59, cor. 8, p. 169).

theoretical one, Fabri tried to "incorporate" the observed trajectory into his theoretical scheme (also developed under the assumption of void!) by resorting to his concocted anti-superposition "destruction mechanism", by which violent impetus is necessarily annihilated *pro rata* lest it exist *frustra*. It should be noted that this *frustra* mechanism seems to destroy the horizontal velocity too fast, and thus might somehow resemble reality only when very high air resistance is involved.

To better understand what motivated Fabri to discard the principle of superposition – shown not to be alien to traditional physics (though never implemented, before Galileo, to an inner analysis of projectile motion) – we must return to Fabri's general conception of the manner in which the discipline of physics should be pursued. In the first part we have already met his claim (in his letter to Mersenne from 1643), that true and "delightful" physics must involve asserting "natural effects" and ultimately reducing them to their causes, while a "natural effect" must be "physically certain and evident – that is, such that it cannot fail (except by miracle)".[61] Galileo's parabola, as Fabri hints in theorem 18 of *De motu mixto ex duobus*, *vel pluribus rectiis* (see note 26 above), is by no means a "natural effect": for this theorem asserts that "there exists no motion which consists of constant [violent] and naturally accelerated [motion]", i.e. an exact parabola, in which the arc of ascent and the arc of descent are equal. What we observe in nature – indeed, "even children who play with a discus" – is that the latter is "by far smaller" than the former. Fabri, therefore, loyal to the general "inertial framework" (thus opting in effect for an analysis in vacuum, and clearly asserting CRM), exhibits also loyalty to the Aristotelian ideal of *scientia*, which must involve a causal explanation of observable phenomena, i.e. reducing natural effects to their causes. No wonder then that Fabri applies to his theory of projectiles an Aristotelian dictum – that nothing in nature exists *frustra* – to account for the validity of the "natural effect" described by hypothesis 3 (which conveys another Aristotelian principle, namely that violent motion is *ipso facto* doomed to die out).[62] In other words, Fabri's analysis – which indeed succeeded in causally explaining the "natural effect" of any projectile (namely its asymmetrical, flattened shape), at the price of rejecting superposition – can be seen as an attempt to preserve a general Aristotelian methodology, despite adopting the bluntly anti-Aristotelian "inertial framework". Perhaps more importantly, it should also be seen as an effort to limit the scope of physics to "natural", i.e. observable effects, and thus avoid Galileo's way of pursuing physics, which was conceived by Fabri and his contemporaries as nothing more than abstract mathematics, which does not pertain to real ("sensible") nature.

Be that as it may, by rejecting the principle of superposition (despite adopting CRM), and using Aristotelian notions (along with *ad hoc* assertions, e.g. that the acceleration downwards is not constant but starts from zero and depends on the

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[61] This is what constitutes, in the eyes of Fabri, an "experiment" (see e.g. Section 4.2 above).

[62] Marin Mersenne also expresses belief in this Aristotelian principle, by claiming that "the movement of missiles which are moved violently go [sic] much more slowly as they are farther from their origin, that is, from the force by which they have been thrown"; Dear 1984, pp. 243–244.

"momentary" inclination) – Fabri illustrates in retrospect Julian Barbour's claim, that "the really important thing about the discovery of the law of inertia was not so much the finding of the law itself as the *demonstration of what could be done with it*".[63]

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[63] Barbour 1989, p. 433; Barbour's emphasis.

Part IV
Fabri and the Eucharist

Chapter 17
The Twofold Mystery of the Eucharist

We have already observed the key role Fabri ascribes to the accident of impetus, on the knowledge of which "the whole of physics depends" (see beginning of Chapter 1 above). But Fabri seems to harbor even higher expectations concerning his favorite concept, which exceed the domain of profane science: he believes, or at least declares to believe, that impetus[1] is not only a means to decipher the secrets of nature, but also the key to solve one of the hardest problems of theology: the mystery of the Eucharist.

In the words of Pietro Redondi, "The Eucharist is the most important sacrament of the Christian religion. Among all the signs that express man's participation in the divine life, the Eucharist is in fact the only one to render Christ not only really present amid men, but also integrally present" (Redondi 1987, p. 207). Although considered "a revealed fact" that "can be proved solely by recurrence to the sources of faith" (Pohle 1909), this sacrament has been the center of a centuries-long philosophical-theological debate among scholastics, all of whom attempted to provide a physical framework (or at least boundaries) for this revealed mystery. This debate, which started between Berengarius and the Benedictines in the 11th century, continued between Dominicans and Franciscans from the 13th century and of course raged between Catholics and Protestants since the beginning of the Reformation, was more or less settled (within Catholicism) in the council of Trent (1545–1563). The council, that aimed at a definitive determination of Catholic doctrines vis-à-vis the Protestants, certainly left room for further discussion (as shown below), but nevertheless highly influenced this debate by authoritatively upholding the doctrine of "Transubstantiation", the total and real conversion of the bread and wine to Christ's flesh and blood (Pohle 1909).

The philosophical debate concerning the Eucharist focused mainly on two issues, or problems, which Fabri – continuing the debate just described, and obviously committed to the decisions of Trent – also attempted to solve:

[1] To be more exact, natural innate impetus, identified with *gravitas*. On Fabri's three types of impetus, see Chapter 8 above.

M. Elazar, *Honoré Fabri and the Concept of Impetus: A Bridge Between Conceptual Frameworks*, Boston Studies in the Philosophy of Science 288,
DOI 10.1007/978-94-007-1605-6_17,

1. The Accidents Problem: the continued existence of the outward appearances (or "accidents") of bread and wine, despite the lack of their natural subjects (*accidentia sine subiecto*). As we shall see, Fabri eagerly assumed the task of handling this problem, in his *Metaphysica demonstrativa* (1648); as a matter of fact, he rather blatantly declared his intention to use it to uphold his own accidents theory, particularly the select status of impetus and heat (and especially impetus).
2. The Real Presence Problem: the problem of explaining the manner in which Christ exists in the host after the consecration, even though what we perceive is bread and wine; or, according to the Catholic Encyclopedia, clarifying "the spatially uncircumscribed, spiritual mode of existence of Christ's Eucharistic Body (*existentia corporis ad modum spiritus*)".[2] We shall see that Fabri finds this problem extremely difficult. In his *Metaphysica demonstrativa* he is trying to isolate (and downplay) Real Presence as much he can, and in his *Physica*, *id est scientia rerum corporearum* (1669), he eventually adopts a drastic solution which amounts to banishing this problem from physics altogether. As will be shown, Fabri's struggle with this mind-boggling problem did not lead, as some historians contend, to rejecting scientific "profane" issues within his physics,[3] but rather to ascertaining the autonomy of physics by transferring this problem to a "higher" realm – metaphysics.

It should be noted that the two problematic issues of the Eucharist[4] in fact constitute the two sides of the same coin, and that the Accidents phenomenon, the persistence of the outward characteristics of bread,[5] is considered as nothing but a second miracle designed to conceal the first (namely, the Real Presence). This "concealment" is necessary for this sacrament, as the renowned preacher and bishop of Meaux Jacques Bénigne Bossuet explains, in order to hide from the believers the "horror" they might feel at the idea of eating His flesh and blood in their own form.[6]

I shall first analyze Fabri's treatment of the Accidents problem (in the *Metaphysica*) and then his solution to the Real Presence problem (in the *Physica*), but before considering these two works I wish to start with Fabri's reference to this issue which can already be found in his *Tractatus physicus de motu locali* (1646). Fabri mentions the Eucharist only once in the *Tractatus*, and the context is theorem 38 of the first book, which claims that "impetus is received naturally only in the very substance of the subject." For example, "if the mobile is hot iron, it [the impetus] is received in the substance itself of the iron" and not in the accident of heat or, for that matter, in any other accident. Fabri goes on to prove this reasonable

[2] Pohle 1909.

[3] Especially the issues of vacuum and atomism (see Section 18.2 below).

[4] The *Catholic Encyclopedia* adds a third central problem, which will not be discussed here: "the simultaneous existence of Christ in heaven and in many places on earth (*multilocatio*)" (Pohle 1909).

[5] For the sake of convenience, I shall usually refer only to the bread, meaning also the wine (which becomes Christ's blood).

[6] Bossuet 1862–1866, vol. 13, p. 75.

proposition, claiming – for instance – that if we were to assume that the impetus of the moving hot iron resided in its heat, we would have to deduce the absurd conclusion that by destroying this heat (cooling the iron) it would necessarily stop moving. Then Fabri adds an "*a priori* reason": "an accident connected to its subject requires that it always be in the subject, because it cannot exist naturally outside the subject." According to standard Aristotelian ontology, of course, an accident cannot exist outside a substance. But later on, Fabri adds an important reservation: "I am speaking here only about accidents within a subject; not about the Eucharistic accidents, which separated from a subject by a miracle can also move by impressed impetus"; and then, in the scholium of theorem 38, Fabri explains that he used the adverb "*naturaliter*" within the formulation of the theorem because "an accident separated from any substance by a miracle, as long as it [i.e. the accident] is impenetrable, can be moved by an impetus which is impressed within it". He adds that entities which are by their very nature incorporeal, like the human soul and angels, can also receive impetus – "if only joined to impenetrability".[7]

So – unlike "ordinary" accidents, e.g. heat in a moving hot piece of iron – the Eucharistic accidents *can* receive impetus, and hence be locally moved; but Fabri explicitly claims that those "subjectless" accidents can only move because of their impenetrability.[8] In the *Metaphysica* Fabri's explanation of the whole process of the sacrament of the Eucharist is much more elaborate; we shall find out that Fabri's use of the accidents "heat" and "impetus" in this theorem from the *Tractatus* mentioning the "Eucharistic accidents" is no coincidence: the only real (or absolute) accidents which remain after the consecration of the bread, according to Fabri, will be impetus and heat (to be more exact: certain kinds of impetus and heat).

Fabri's full explanation of the Eucharistic Accidents problem is set out in the fifth book of his *Metaphysica*, entitled *De accidente*. The last third of that book is exclusively devoted to the Eucharist, but as we have seen (in Section 4.1 above) this subject is mentioned already at the beginning. As we recall, impetus and heat – as the only two non-modal accidents – are unique in their ability to be separated (by a miracle) from the subject in which they inhere. Unlike modal accidents (i.e. modes), which do not "inhere" in substances but "adhere" to them, these non-modal accidents can be perceived by the mere "secondary formal effects" (motion and expansion/dissolution) which they cause in their subjects. This ability to be perceived without an actually present subject is the "source of the separability of a

7 "Impetus recipitur tantum in ipsa substantia subiecti naturaliter. v. g. si mobile sit ferrum calidum, recipitur in ipsa substantia ferri; non vero in ipso calore (ex suppositione quod calor sit accidens, ut alias demonstrabimus); nec in aliis accidentibus, si quae sunt, in eodem subiecto. . .Ratio a priori esse potest; quia accidens cum suo subiecto coniunctum exigit semper esse praesens subiecto, cum naturaliter extra subiectum existere non possit. . .Scholium: Observabis primo In hoc Theoremate dictum esse naturaliter; quia per miraculum accidens separatum ab omni substantia, dum sit impenetrabile, per impetum sibi impressum moveri potest. . . Observabis tertio etiam Animam rationalem separatam, modo sit cum impenetrabilitate coniuncta, capacem esse impetus; quem etiam a potentia motrice corporea recipere potest; idem dictum esto de Angelo; sed de utroque alias" (Fabri 1646, lib. 1, th. 38, p. 29).

8 The significance Fabri ascribes to impenetrability will be discussed below.

non-modal accident", explains Fabri, and "from this philosophical principle the matter of the so called Eucharistic accidents, or species,[9] is excellently confirmed, from which it is held that these accidents can exist separately, by the will and command of God".[10]

The very correlation of this division (between non-modal and modal accidents) with the problem of the Eucharist is not peculiar to Fabri; As the entry "Accident" in *The Catholic Encyclopedia* explains, "the teaching of Catholic philosophy on the distinct reality of certain absolute, not purely modal, accidents was occasioned by the doctrine of the Real Presence of the Body and Blood of Christ in the Eucharist" (Siegfried 1907). Furthermore, we have already seen (also in Section 4.1) that the criterion of separability, used to distinguish between non-modal accidents and modal ones (i.e. modes), has already been introduced by Suárez. However, choosing impetus and heat as the only non-modal accidents, and therefore the probable (or indeed necessary) candidates to participate in accounting for the Accidents problem, is most probably Fabri's idiosyncratic idea. Fabri himself admits, in proposition 60 of the chapter *De accidente*, that his proposal does not conform to the "common opinion" (Section 18.1 below). It is also worth noting that the *Ordinatio pro studiis superioribus* of 1651 explicitly condemned the statement "there are more sensible primary qualities of elements than four",[11] i.e. beyond the traditional heat, cold, dryness and humidity: therefore the mere inclusion of impetus (though not heat) among the non-modal accidents must have seemed questionable, if not suspicious.

Having explained, early in *De accidente*, the difference between non-modal and modal accidents (i.e. modes), Fabri objects to "some recent [scholars], especially an author of Peripatetic institutions,"[12] who claim that "there is no authority, nor any demonstration, which would prove that an accident could be conserved outside a subject". Fabri answers:

> I say that it can by miracle, for he [that unnamed Peripatetic] claims that it is a contradiction, that some accident would exist outside a subject; but no [such] contradiction can be alleged for a non-modal accident; besides, it is certain that there exist Eucharistic species, under which the body of Christ really lies hidden [*latet realiter*]; besides it is certain that nothing of the substance of the bread survives; therefore I further conclude that there is not any other substance, besides the body of Christ, along with the other things, which are concomitant and also supposed; as Theologians correctly show.[13]

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[9] The important term "species", and its relation to the Aristotelian concept of "accidents" will be soon discussed.

[10] "Haec est radix separabilitatis accidentis non modalis... ex hoc principio philosophico, optime confirmatur res accidentium, seu specierum Eucharisticarum (ut vocant) ex quo habetur seorsim accidentia illa posse existere, Deo scilicet volente, atque iubente" (Fabri 1648, lib. 5, prop. 20, p. 173).

[11] *Ordinatio pro studiis superioribus (1651)*, in Pachtler 1887–1894, vol. III, prop. 40, p. 93.

[12] Fabri does not mention a name.

[13] "... unde reiicies aliquos recentiores, praesertim institutionum peripaticarum autorem, qui lib. 4, lect. 2, n. 4, haec verba habet, nullam esse, neque authoritatem, neque demonstrationem in Theologia, quae convincat accidens posse conservari extra subiectum; posse inquam per miraculum, nam ipse contendit esse contradictionem, ut accidens aliquod existat extra subiectum, sed

So already before the full treatment of the Eucharist Fabri proclaims his adherence to the Catholic dogma, and explains (again, according to common knowledge) that the idea of non-modal accident can be used – notwithstanding Aristotle's absolutely contrary opinion – to explain the existence of "subjectless" accidents. But here Fabri's conformity ends; as we shall soon find out, Fabri adamantly rejects the standard Thomistic solution to the Accidents problem, which involves the rather elusive accident of quantity (Fabri's analysis uses – as already mentioned – impetus and heat instead); furthermore, Fabri will be shown to entertain a deviant atomistic view of Christ's Real Presence in the host, a view specifically damned by Jesuit authorities; finally, Fabri will eventually neutralize every physical aspect of Real Presence, turning it into a purely metaphysical issue, while accordingly emphasizing (and even "substantializing") the accidents impetus and heat – thus in a way approaching the heretic theory of consubstantiation.

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nulla afferri potest contradictio pro accidente non modali; praeterea certum est, esse species eucharisticas, sub quibus latet realiter corpus Christi; certum est praetere, nihil superesse substantiae panis; unde colligo ulterius, nihil etiam inesse alterius substantiae, praeter corpus Christi, cum aliis, quae concomitantur etiam ponuntur; ut recte ostendunt Theologi" (Fabri 1648, lib. 5, prop. 20, p. 173).

Chapter 18
De accidente: Impetus and the Accidents Problem

We arrive now at Fabri's full-blown treatment of the Eucharist, contained in the last third of the chapter *De accidente* in his *Metaphysica*, and also in his *Physica*: in the first book (*liber primus*) – entitled "on corporeal quantity" (*De quanto corporeo*) – of the first treatise (*tractatus primus*), which itself bears the name "on the sensible states of bodies" (*De corporum statibus sensibilibus*).

Fabri's lengthy discussion on the miracle of the Eucharist starts in the chapter *De accidente* as a scholium to a proposition dealing with the non-at-all-miraculous accident of impetus. Not only the setting, but also the point is very similar to the issue dealt with in the *Tractatus*: "when an accident – which is in a subject – moves," says proposition 51, "it moves by the impetus of the subject".[1] Again, to use the aforementioned example of a moving chunk of hot iron: as far as we are permitted to say that the heat in the iron "moves", we can only claim that it moves due to the impetus which is impressed in the *subject* of the hot iron. Now comes the scholium, in which Fabri in effect enlists the solemn issue of the Eucharist to exhibit the explanatory prowess of "our principles":

> Notice that hardly has a dispute ever developed upon the accidents without the Eucharistic accidents immediately being evoked, in order either to strengthen one's own opinion or to weaken the opinion of an adversary; therefore I thought it is our business to show briefly and by the way how easily and how suitably, supposing the Institution [of the sacrament],[2] according to our principles, everything which pertains to the aforementioned Eucharistic accidents may be explained.[3]

[1] "Quando accidens, quod inest subiecto, movetur, movetur per impetum subiecti" (Fabri 1648, lib. 5, prop. 51, p. 183).

[2] Christ's words, "This is my body" and "This is my blood" – which are always repeated by the priest administering the Eucharist – are considered to "institute" this important Sacrament and effect the Transubstantiation of the bread and the wine into Christ's body and blood. See *The Oxford Dictionary of the Christian Church* [Cross and Livingstone 1974], s.v. "Institution, The Words of". See also *Mediae latinatis lexicon minus* [Niermeyer 1976], s.v. "Institutio", 5th meaning ("liturgical custom").

[3] "Observabis, vix unquam disputationem oriori de Accidentibus, quin accidentia Eucharistica statim accersantur, tum ad propriam confirmandam, tum ad infirmandam adversarii sententiam; quare e re nostra esse putavi, brevi, atque obiter ostendere, quam facile, quam apposite, supposita

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Fabri now presents four statements (*positiones*) taken *de fide* explicitly from the canons "concerning the most holy sacrament of the Eucharist", decided upon in the Thirteenth Session of the council of Trent.[4] Here is Fabri's formulation:

1. Christ exists really and truly under the species of the Eucharist.
2. The whole of Christ is contained under single parts of each species.
3. After the consecration nothing of the substance of the bread and wine remains in the Eucharist, which is totally converted into the flesh and blood of Christ.
4. After the consecration only the species of the bread and wine remain in the Eucharist.[5]

First, it should be mentioned that the canons formulated by the Council of Trent were considered binding, while the "chapters" (*capita*) were less compelling and treated as "recommendations" (Moloney 1995, p. 160). Now it is worth noting several points that emerge from these canons, as expressed by Fabri:

1. The term "species": the Council of Trent had preferred to use this "patristic" and "non-professional" term, usually translated as "appearances" (and sometimes referring simply to each of the substances involved in the ceremony, i.e. bread and wine), rather than the official Aristotelian term *accidentia*, probably as a compromise between opposing factions, especially Thomists and Scotists.[6] Descartes, for instance, exploited this vagueness to claim that the term actually means "surface" (*superficies*), and came up with an explanation that suited his own theory of substance and its properties.[7] We shall soon observe that Fabri, for his part, makes it clear that by "species" he means "accidents" (when he is not referring simply to the substances of bread and/or wine).
2. The manner of Christ's Real Presence: according to the first canon (as expressed by Fabri), Christ exists "really and truly" (*realiter & vere*) in the consecrated host. However, the first canon as formulated by the Council of Trent determines that Christ exists "*vere*, *realiter* ***et substantialiter***" under the species.[8] In Fabri's

institutione, iuxta nostra principia, cuncta explicentur, quae ad praedicta accidentia Eucharistica pertinent" (Fabri 1648, prop. 51, scholium, p. 184).

4 *Canons and Decrees of the Council of Trent* [Schroeder 1978], pp. 79–80.

5 "Positio prima: Christus est realiter & vere sub speciebus Eucharisticis; habetur in can. 1, s. 13, conc. trident. Positio secunda: Christus totus sub singulis cuiusque speciei partibus continetur; habetur in can. 3. Positio tertia: Post consecrationem in Eucharistia nihil remanet substantiae panis, & vini, quae tota in corpus, & sanguinem Christi convertitur; est can. 2. Positio quarta: Post consecrationem in Eucharistia remanent species dumtaxat panis & vini; est can. 2" (Fabri 1648, prop. 51, scholium, p. 184).

6 Powers 1967, pp. 40, 140–146; Ariew 1999, pp. 183–184; Bourg 2001, p. 130; Moloney 1995, p. 163.

7 "Author's Replies to the Fourth Set of Objections", in *Objections and Replies*, in Descartes 1984–1985, vol. II, pp. 173–178. While Descartes' attempt to thus solve the Accidents problem seems not to have caused much trouble, such is not the case concerning his handing of the Real Presence problem (see Section 19.4 below).

8 The original Latin text appears in Schaff 1887, vol. II, p. 129.

formulation, the adverb *substantialiter* has disappeared, and Fabri's subsequent analysis will make it clear that this omission is not accidental.

3. Christ being contained "in whole" under "single parts of every species": this is indeed a faithful quotation of the original canon III, but Fabri will apparently use it to develop (in proposition 82) an atomistic account of the Real Presence of Christ (described in Section 18.2 below).
4. The absence of the term Transubstantiation: this important Catholic concept, unequivocally adopted already by the Fourth Lateran Council (1215), and authoritatively reaffirmed by the Council of Trent, does not appear at all within Fabri's analysis, and it is only mentioned at the end of *De accidente* in very general terms.[9] In Fabri's *Physica*, where he takes up the question of Christ's Presence, this term does not appear at all. It is true that Fabri, by claiming that only the *species* of bread and wine (and nothing of their substances) remain, thus rejects the theory of Consubstantiation[10] – the Lutheran adversary to the Catholic Transubstantiation; furthermore, never does he openly renounce Transubstantiation. However, his evident inclination not to use this term is significant. As we shall find out, Fabri does not reject Transubstantiation but certainly regards it as a doctrine which is extremely difficult (impossible, actually) to explain in *physical* terms.

18.1 Impetus – The Substitute for Substance

Fabri begins to keep his promise – namely, show how the miracle of the Eucharist supports his own theory of accidents – by asserting that the "species" concerned must indeed be accidents. To assume that they are not – therefore, assume that they are substances – would contradict statement (*positio*) 3, which denies the existence of any substance of the bread following the consecration.[11] Fabri directly concludes (in a somewhat tautological manner) that the remaining species prove that "there has to exist, necessarily, a certain accident really distinct from all substance", and therefore there must exist "a certain accident separated from all substance".[12] Now he claims that "these species do not inhere in the body of Christ", since He cannot be affected by them – for instance, by the bread's round shape and white color; and also because He cannot receive any formal effect of an inhering accident, e.g.

[9] In the last proposition: "Explicari potest transubstantiatio. . ." (Fabri 1648, lib. 5, prop. 85, p. 194).

[10] Namely, the assumption that these substances coexist with Christ's substance in the consecrated host. But as will be shown (in Section 18.1 below), Fabri's subsequent explanations do bring to mind this assumption.

[11] Fabri 1648, lib. 5., prop. 52, p. 184. As Fabri has emphasized already in the *Tractatus*, "whatever exists, is either a substance or an accident" ("Quidquid existit vel est substantia, vel accidens"; Fabri 1646, lib. 1, ax. 6, p. 6).

[12] "Propositio 52: Debet necessario dari aliquod accidens ab omni substantia realiter distinctum. . . Propositio 53: Ex hoc Sacramento habetur, dari aliquod accidens ab omni substantia separatum" (Fabri 1648, lib. 5, prop. 52, p. 184 and prop. 53, p. 185).

heat, which rarifies.[13] Now Fabri asserts that in order to avoid an infinite regress of modal accidents inhering in each other we have to assume a non-modal accident in the Eucharist:

> Proposition 55: by this sacrament, it is held that a certain non-modal accident exists. It is proved, for according to prop. 52 an accident which is distinct from all substance is held to exist; it is also separated from all substance, by prop. 53 and prop. 54, therefore it is held that there exists something non-modal: because a modal accident is always in something else; therefore even if one accident could be in something else; because there is not any substance besides Christ (statement 3), and [because] the species do not inhere in Christ (prop. 54), since there cannot be an infinite process; and [because] two accidents cannot mutually inhere one in another; certainly some accident must exist which adheres to nothing; but by the definition of mode it is not modal; therefore by this sacrament a certain non-modal accident exists.[14]

Now an obvious question arises as to the identity of the non-modal accident (or accidents) on which all the modal accidents depend. Fabri is of course familiar with Thomas Aquinas's well known solution to the Accidents problem: the Angelic Doctor declared the bread's quantity as the accident that functions as a subject to all the remaining characteristics. We already know that Fabri had other accidents in mind, and that he felt no obligation to obey Loyola's dictum to follow Thomas in theology and Aristotle in philosophy (see Section 14.3 above), so it is no wonder that he explicitly rejects Thomas's suggestion and claims that quantity cannot perform this function.[15] I shall return later to the important issue of quantity and the Thomistic tradition of interpreting the Eucharist; now I wish to focus on Fabri's proposal, which, as he himself admits, deviates from the "common opinion".[16] After rejecting the option of quantity, Fabri returns to the matter of the "species", and explains that some of them must be modes (i.e. modal accidents), "for nothing forbids certain sensible species or sensible accidents from being modal; such as, e. g., humidity, hardness, dryness, opacity, etc.", thus defying an important Aristotelian

[13] "Propositio 54: Illa species non inhaerent corpori Christi, patet, nec enim Corpus Christi ab illa figura circulari, dicitur circulare, nec ab albedine denominatur album &c. [. . .] quippe ad hoc ut accidens dicatur unitum subiecto, scilicet per inhaesionem, debet in eo subiecto habere suum effectum formalem; v.g. calor rarefactionem; igitur ubi calefiunt species rarefaceret Corpus Christi, quod dici non potest" (Fabri 1648, lib. 5, prop. 54, p. 185).

[14] "Propositio 55: Ex hoc Sacramento habetur dari aliquod accidens non modale; Prob. habetur dari aliquod distinctum ab omni substantia, per p. 52. Itemque ab omni substantia separatum, per p. 53, 54, igitur habetur dari aliquod non modale; quia modale semper alteri inest; igitur licet unum accidens alteri insit; cum nulla sit substantia, praeter Christum, per posit. 3, nec Christo inhaereant species, per p. 54, cum non detur processus in infinitum; nec duo accidentia sibi mutuo inhaereant; certe aliquod accidens esse necesse est, quod nulli adhaereat; sed illud est non modale, per d. modi; igitur ex hoc Sacramento habetur dari aliquod accidens non modale" (Fabri 1648, lib. 5, prop. 55, pp. 184–185).

[15] Fabri 1648, lib. 5, prop. 56, p. 186 and prop. 60, p. 187 and prop. 64, p. 188.

[16] See the quotation from proposition 60 (Note 20 below).

principle advocated by the Jesuit authorities.[17] He concludes that since, as being modes, they have to exist in something, in the absence of any appropriate substance (for the only post-sacrament substance is Christ, in which they cannot inhere) they necessarily exist in the non-modal accidents.[18]

Now Fabri comes close to his crucial point. If there could be found, he says in proposition 60, a certain non-modal accident "which would always remain, as long as the species remain", there would be no need to assume another accident (i.e. Thomas's quantity) by which the "sacramental species are sufficiently saved". He claims that "just as in the common opinion, in which a distinct quantity in which other accidents inhere the aforementioned species are saved, entirely likewise in this hypothesis,[19] if only a certain non-modal accident existed, which would perform the function of quantity, i.e. would be extended impenetrably and to which the other modes would adhere – those species will be sufficiently saved".[20]

Fabri, then, does not deny that his opinion is entirely against the "common opinion", set by Thomas Aquinas's Eucharistic doctrine, but he still has to outline his exact opinion on this matter. As we know, both impetus and heat are Fabri's only non-modal accidents, i.e. they are the only possible candidates to replace quantity in "saving" the Eucharistic accidents. So Fabri continues his analysis, and explains why heat cannot solve the problem by itself:

> Proposition 61: it cannot be said that only heat performs this function; because it is possible that all the heat in a certain part would be destroyed, although the species remain; to understand this better, I suppose that in these species only that heat is destroyed (for instance, by applying coldness) which would be destroyed in the substance of the wine (for instance) if it were present [after the consecration]; I also suppose that in the substance of the wine there is a double reason of heat: firstly, of that which is in the particles of fire; secondly, of the

[17] "Propositio 57: Ex hoc Sacramento, non evincitur omnes illas species, quibus subest corpus Christi, esse accidentia non modalia; Nihil enim vetat, quin aliquae species sensibiles, vel accidentia sensibilia sint modalia; talis est v.g. humiditas, durities, siccitas, opacitas & c." (Fabri 1648, prop. 57, p. 186). Fabri's "downgrading" of the ontological status of the traditional primary qualities humidity and dryness to modes sharply contradicts, for instance, the *Ordinatio pro studiis superioribus* of 1651, which condemned the claim that only "*calor et frigus*" (and not "*humor et siccitas*") are primary qualities; *Ordinatio pro studiis superioribus*, prop. 39, in Pachtler 1887–1894, vol. III, p. 93.

[18] "Propositio 59: Accidentia modalia adhaerent in hoc Sacrameno non modalibus; Probatur, adhaerent alicui, per d. modi; non corpori Christi, per p. 54, non alteri substantiae; quia nulla est, per posit. 3. Igitur necessario adhaerent aliis accidentibus non modalibus" (Fabri 1648, lib. 5, prop. 59, p. 187).

[19] Namely, Fabri's. Note that the meaning of "hypothesis" here is different from the one which Fabri generally assumes (see beginning of Chapter 2 above) and closer to the standard (i.e. "hypothetic") meaning of the term.

[20] "Propositio 60: Modo sit aliquod accidens non modale, quod semper remaneat, dum manent species, & cui alia scilicet modalia adhaereant, aliud certe non evincetur ex hoc Sacramento & sufficienter salvantur species sacramentales; Probatur, quemadmodum in communi sententia, in qua datur quantitas distincta, cui alia accidentia inhaerent; sufficienter praedictae species salvantur; ita prorsus in hac hypothesi, modo detur aliquod accidens non modale, quod munere quantitatis defungatur; id est, quod extendatur impenetrabiliter, & cui alia modalia adhaereant, sufficienter praedictae species salvabuntur" (Fabri 1648, lib. 5, prop. 60, p. 187).

> other [heat] that inheres in the particles of the other elements; for wine is a mixture, which is made of elements, potentially (*potentia*) physically and sensibly, but actually (*actu*) entitatively (*entitative*) and insensibly;[21] accordingly those insensible particles of fire, which nevertheless if assembled together create sensible fire, have their highest heat possible, by whose effort they act on nearby particles and entirely conserve the heat produced in them as long as they remain applied. Furthermore, primary heat is always the same *in entitate*; it is not however always the same *in virtute*; *in entitate*, indeed [it is the same] because any particle of heat always has its highest possible heat (as they say); but *in virtute* that same heat does not always remain, because sometimes the *virtus* is greater, namely when more parts of fire are assembled, since they all act by a common action in a common medium; sometimes it is smaller, whenever they are divided among more [non-fiery parts].[22]

So Fabri assumes (quite reasonably) that the destruction of heat in the host occurs in the same way as if the substances of the bread and wine had remained, and then claims that the possible diminishing of heat consists of the destruction not of "primary heat *in entitate*", i.e. heat of fire particles per se, but only of "primary heat *in virtute*". Elsewhere Fabri maintains (thus clarifying this point) that "to extinguish fire is nothing other than to disperse it into parts so fine and insensible that they constitute something other than fire; for example, in wood, they are of wood".[23] Therefore he may claim that "primary heat" per se – resulting from fire having its "highest possible heat" actually (i.e. *in entitate*) but in a way we cannot feel (i.e. *insensibile*) – remains the same, whereas primary heat *in virtute* – resulting from the mutual interaction of elemental particles within the mixture[24] – depends on momentary conditions, such as the surrounding heat (or cold) and the current distribution of fire particles among other elements, and thus might be destroyed. In the remainder of

[21] According to the Aristotelian notion of "mixture", "the ingredients act to change each other so that they cease actually to exist, but they continue to exist potentially"; Wood and Weisberg 2004, p. 682.

[22] "Non potest dici quod solus calor defungatur hoc munere; quia potest fieri, ut totus calor destruatur in aliqua parte, licet remaneant species; quod ut melius intelligatur, suppono illum tantum calorem destrui in his speciebus, ab applicato v.g. frigore, qui destrueretur in ipsa substantia vini, v.g. si adesset, praeterea suppono in substantia vini duplicem esse rationem caloris; prima est illius, qui particulis ignis inest, secunda alterius, qui particulis aliorum elementorum inhaeret; nam vinum est mixtum, quod constat ex elementis, potentia quidem physice, & sensibiliter; actu vero entitative, licet insensibiliter; ac proinde illae particulae ignis insensibiles, quae tamen si colligantur, ignem faciunt sensibilem habent suum calorem, illumque in summo, cuius opera agunt in particulas vicinas aliorum elementorum, productumque in eis calorem, quamdiu manent applicatae omnino conservant: porro primus calor idem semper est in entitate; non tamen semper idem in virtute; in entitate, quidem, quia quaelibet particula ignis semper habet suum calorem in summo, ut aiunt; at vero in virtute, non manet semper idem calor, quia modo maior est virtus, cum scilicet plures ignis partes collectae sunt, quippe agunt omnes actione communi in commune medium; modo minor est, quando sint in plures divisae" (Fabri 1648, lib. 5, prop. 61, p. 187).

[23] Des Chene 2001, p. 375, n. 23 (I have slightly modified Des Chene's translation): "[Respondeo] ignem extingui nihil est aliud, nisi in partes exiguas & insensibiles ita difflari, ut iam esse aliud quam ignis conflent, v.g. in ligno, esse ligni" (Fabri 1669–1671, tr. 6, lib. 1, prop. 17, p. 217; note that the reference given in Des Chene's atricle – prop. 10 – is mistaken).

[24] According to Aristotle's view "mixture is the unification of ingredients as a result of their mutually acting on each other and undergoing action. The mutual interaction of the ingredients establishes an equilibrium between their powers" (Wood and Weisberg 2004, p. 682).

proposition 61 Fabri explains that the diminishing of primary heat *in virtute* results in the diminishing of secondary heat, that is to say heat indirectly produced by fire particles and dispersed between the rest of the elements, and therefore heat alone is not enough to explain the Accidents problem of the Eucharist: for a part of the *species* that has secondary heat only might easily lose all its (sensible) heat, and yet still exist. We still need, therefore, another non-modal accident, which continues to exist (in any part of the species whatsoever) as long as the species do.[25]

In proposition 62 Fabri explains again briefly how secondary heat might diminish[26] and furthermore asserts that "all the secondary heat inheres in another non-modal accident in the Eucharistic species".[27] Now he is ready to name that other non-modal accident which, being always present in any substance, saves the day:

> Proposition 63: innate impetus before the consecration is in (*inest*) all the particles of the elements. It is not distinguished from absolute gravity; therefore since absolute gravity is in all particles (for there is no absolute levity, as we shall prove in the next book), hence it necessarily occurs that before the consecration innate impetus is in all the particles of the elements; we shall then call this impetus innate, or "primary", and the other "secondary", whether impressed by an extrinsic agent [i.e. violent] or acquired from inside.[28]

It is fascinating how Fabri uses a Galilean and completely non-Aristotelian idea – the non-existence of levity – to prove the theological part played by his select non-modal accident, i.e. impetus: if "absolute levity" were to exist, then we would not

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[25] "Igitur ille calor, qui ante consecrationem inerat particulis ignis, quae componunt substantiam panis & vini, intactus deinde manet post consecrationem, scilicet in entitate; quia eo modo manet, quo maneret, si adesset substantia ignis [Fabri uses here the abovementioned 'assumption']; sed si haec adesset; non destrueretur ille calor, igitur maneret idem in entitate, non tamen in virtute, ut dictum est; at vero ille calor, qui ante consecrationem inerat particulis aliorum elementorum, post consecrationem non manet intactus, quippe destrui potest, eo modo, quo destrueretur si adessent particulae illae aliorum elementorum, quibus inerat ante; sed tunc omnino posset destrui, quia cum conservetur a calore, qui inest particulis ignis, scilicet ante consecrationem, & cum hic calor primarius (sic eum vocemus) licet non imminuatur in entitate, imminuatur tamen in virtute; igitur imminuitur etiam illius effectus, qui est calor secundarius; igitur destrui potest totus calor secundarius alicuius partis specierum, quae scilicet nihil habet caloris primarii, licet maneat praedicta illa pars speciei; igitur praeter calorem debet dari aliquod accidens non modale, in quo scilicet illa pars praedicta quasi subsistat" (Fabri 1648, prop. 61, pp. 187–188).

[26] "Sometimes more particles of primary heat are assembled, and sometimes less, therefore they sometimes act more powerfully, sometimes less, therefore they sometimes produce more secondary heat, sometimes less (particulae caloris primarii modo sunt plures collectae, modo pauciores, igitur modo maiore vi pollent ad agendum, modo minore, igitur modo plus caloris secundarii producunt, modo minus)"; Fabri 1648, lib. 5, prop. 62, p. 188.

[27] "Propositio 62: Totus calor secundarius inhaeret alteri accidenti non modali in speciebus Eucharisticis" (Fabri 1648, lib. 5, prop. 62, p. 188).

[28] "Propositio 63: Impetus innatus ante consecrationem, omnibus particulis elementorum inest; hic non distinguitur a gravitate absoluta; igitur cum gravitas absoluta omnibus corporibus insit (nulla est enim levitas absoluta, ut tomo sequenti demonstrabimus) certe hinc necessario sit ante consecrationem impetum innatum omnibus particulis elementorum inesse; hunc impetum, innatum deinceps appellabimus vel primarium, alium vero secundarium, sive impressum ab agente extrinseco, sive ab intrinseco acquisitum" (Fabri 1648, lib. 5, prop. 63, p. 188).

be allowed to claim that (natural innate) impetus exists everywhere in matter, so we could not use it (as Thomas had used the accident of quantity) as a "carrier" for all the Eucharistic accidents, or species.[29] Fabri then concludes: "hence that innate impetus, remaining after the consecration inheres in nothing else; I say the same about primary heat. The reason is that you will not be able to prove by that sacrament [that] any other non-modal accident [exists] except those two among the sensible species".[30]

Now Fabri arrives at another important point – each "primary non-modal accident", i.e. innate impetus and primary heat, functions as an impenetrable body, otherwise the whole sacrament would be impossible:

> Proposition 67: the primary [non-modal accident] is in a state of body, i.e. in a state of impenetrability; as is agreed; indeed supposing the Institution [of the sacrament] this state is connatural to it, in order to reach its end, for were it not connected to impenetrability, it could not be moved, touched, perceived etc.[31]

Fabri claims that actually God interferes here and "supplies this accident with the power to perform the function of substance",[32] and adds that this should actually not be seen as a real new miracle, but rather as a direct non-miraculous intervention of God intended to "conceal the mystery", i.e. hide from the believers the Real Presence miracle.[33]

So this is Fabri's basic explanation for the sacrament of the Eucharist: the primary non-modal accidents not only serve as the bearer of all the other (modal) accidents, but also – *pace* Aristotle – are empowered by God to act as a substance, and thus they "conceal the mystery", i.e. conveniently hide from the participants the fact that after the consecration they eat and drink the flesh and blood of Christ.

Fabri is clearly only too eager to confer this great honor and responsibility upon the two non-modal accidents. He prefers impetus, for as we have seen heat alone

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[29] Fabri's abolition of levity, i.e. the "absoluteness" of gravity, as well as the identification of the latter with innate impetus have been already discussed in Section 7.1 (and also Chapter 8) above.

[30] "Propositio 64: Hinc impetus ille innatus, post consecrationem manens nulli alteri inhaeret, idem dico de calore primario; ratio est, quia inter species sensibiles, nullum aliud accidens non modale, praeter haec duo ex hoc Sacramento evinces" (Fabri 1648, lib. 5, prop. 64, p. 188).

[31] "Propositio 67: Primarium est in statu corporis, id est, in statu impenetrabilitatis; ut patet; imo supposita institutione, hic status est illi connaturalis, ut suum finem consequatur, nisi enim esset cum impenetrabilitate coniunctum, non posset moveri, tangi, sentiri, &c." (Fabri 1648, lib. 5, prop. 67, p. 189).

[32] "Deus supplet accidentis vim, quatenus substantiae munere defungitur" (Fabri 1648, lib. 5, prop. 67, p. 189).

[33] "Ego novum [miraculum] pono, quod facile intelligitur & quod posita institutione res ipsa exigit; igitur miraculum vel eo nomine vix esse dicam; imo nisi Deus hunc effectum suppleret, statim miraculum appareret; igitur posito illo decreto institutionis, quo mysterium occultari debet, si Deus effectum illum suppleat, qui necessarius est ad occultandum miraculum, absolute dico sub hac ratione non esse novum miraculum" (Fabri 1648, lib. 5, prop. 67, p. 190). Perhaps Fabri wishes to "minimize" the required number of miracles. In any case, he is clearly reluctant to regard our "common sense" experience – the continued existence of the species – as an additional miracle.

(which ultimately inheres only in the particles of fire) will not do. But if these accidents are so important and fulfill all the "duties" of substance, where does that leave the substance that *really* lies (according to Doctrine) under the host, i.e. the substance of Christ? We have seen (in the beginning of this chapter) that Fabri explicitly stated that only the "species" of the bread survive the consecration; however, by thus "substantiating" two of them – namely, impetus and heat – does he not approach, to some extent at least, the Lutheran heresy of Consubstantiation? Furthermore, we have already noticed that Fabri omitted the adverb *substantialiter* that characterizes Christ's mode of existence in the Eucharist according to the Thirteenth Session of *The Canons and Decrees of the Council of Trent*. Although the full-blown treatment of the subject of "body" (*corpus*) in general and Christ's body within the host in particular appears in Fabri's *Physica* (which will be examined soon), it can already be observed in *De accidente* (of the *Metaphysica*) that Fabri's omission was hardly a coincidence, as we shall now see.

Already before the important proposition 67, Fabri describes how a secondary non-modal accident (i.e. "non-fiery" heat, violent impetus or natural acquired impetus) is destroyed within the host: "a non-modal secondary accident is destroyed in the Eucharist exactly in the same way in which it would be destroyed, if the substance of the bread (in which it inhered) were still present".[34] Likewise, the primary accidents are destroyed exactly in the same manner in which they would have been destroyed "if the substance of the bread were present".[35] So as far as the destruction of the *species* is concerned, the conversion of the bread to the flesh of Christ made no difference whatsoever.

In proposition 72 Fabri claims that because the primary accidents are in a bodily state, any "extrinsic agent" will act on them "connaturally", and thus they could "be affected (*pati*), moved, heated": they can be moved by impetus impressed extrinsically, or be rarefied by external heat, and so on.[36] In the following proposition, however, he explains not how these accidents are affected, but how they affect us:

> These accidents imprint sensible affections on the senses, e.g. they reflect light, and they do not strike the eyes in any other way; they affect smell by an emitted odoriferous vapor; for smell cannot be communicated in any other way; for the body of Christ is no longer under that smell, which is brought to the nose; whether it is really a diffusion of an accident or whether a vapor; hence immediately a new substance is substituted [instead of this "diffusion" or vapor[37]], similar to that which would really exist if this vapor were to fly away

[34] "Propositio 65: Accidens non modale secundarium destruitur in Eucharistia, eodem prorsus modo, quo destrueretur, si adesset substantia panis, cui ipsum inesset" (Fabri 1648, lib. 5, prop. 65, pp. 188–189).

[35] Fabri 1648, lib. 5, props. 74–75, p. 191.

[36] Fabri 1648, lib. 5, prop. 72, p. 191.

[37] An alternative interpretation is to identify the "new substance" with the body of Christ. However, such an interpretation would turn Fabri into a downright heretic, since in such case Real Presence would last for only a brief period of time. Besides, it would be hard (though not impossible) to reconcile such an interpretation with Fabri's subsequent propositions (e.g. prop. 79, p. 192), according to which Christ exists under the host until it is "corrupted".

> from the substance of the bread, and there is no difficulty with this; likewise they affect other senses, entirely in the same way in which the substance of the bread would have brought it about, had it been present.[38]

Thus Fabri manages to "save our senses" – i.e. avoid the assumption that they are lying to us (telling us that we see bread, while it is Christ who really subsists there) – by completely isolating the underlying reality of Christ from any external action that might be applied to the host, as well as from any sense data which might originate in the host and reach us.

Fabri's subsequent explanations further testify to the limited (or isolated) place he allocates to the Real Presence, as compared with the importance he attributes to the accidents which solve the Accidents problem. In proposition 80 he explains that the consecration must destroy the original substance of the bread, "for since the accidents must be separated from every subject, as was said above, that substance – having become devoid of all accident – would obviously be in vain, but whatever is in vain, does not have to be conserved".[39]

Fabri emphasizes here that according to his general (basically Aristotelian) belief that whatever is in vain (*frustra*) does not survive,[40] a substance without accidents – i.e. a substance which does nothing, and nothing is done to it – exists in vain, and therefore will not ne conserved. Soon afterwards Fabri asserts that Christ is not united "physically" to the species, but only morally, or sacramentally,[41] and therefore when the consecrated host moves, He does not move by an (external) impetus impressed on Him, but rather by an impetus impressed on the species; furthermore,

> Christ under these species cannot move Himself by a natural force, for natural motion requires the use of muscles, which Christ lacks, because all his parts penetrate each other, etc. Hence he cannot speak, see, sense by natural power etc, because these signify motion of parts; also he cannot be affected by any natural agent: He cannot be divided, nor burned, be rotated, drawn tight and so on.[42]

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[38] "Propositio 73: Haec accidentia imprimunt sensibus affectiones sensibiles, v.g. lumen reflectunt, nec alio modo feriunt oculos; olfactum afficiunt per emissum odoriferum halitum; nec enim alio modo, odor communicari potest; nec enim amplius sub illo odore, qui naribus admovetur, est corpus Christi; sive sit vera accidentis diffusio sive halitus; hinc statim nova substituitur substantia, similis illi, quae revera esset, si hic halitus ex substantia panis avolaret, nec in hoc ulla difficultas; pari modo alios sensus afficiunt, eodem prorsus modo, quo id praestaret substantia panis, si praesens adesset" (Fabri 1648, lib. 5, prop. 73, p. 191; emphasis mine).

[39] "Propositio 80: Substantia illa per consecrationem debet destrui; quia cum accidentia ab omni subiecto debeant esse separata, ut supra dictum est, substantia illa omnino accidente spoliata, esset frustra, ut patet, sed quod frustra est, conservari non debet" (Fabri 1648, lib. 5, prop. 80, p. 192).

[40] A principle which, as we recall from Part III, Fabri uses also to analyze projectiles.

[41] "Christus cum speciebus non facit unum totum Physicum, sed unum morale, id est unum Sacramentum" (Fabri 1648, lib. 5, prop. 83, p. 193).

[42] "Christus sub his speciebus vi naturali non potest se ipsum movere; quia ad motum naturalem requiritur musculorum usus, quo Christus caret; quia omnes partes inter se penetrantur, &c. Hinc non potest loqui, videre, sentire naturali virtute, &c. quia haec dicunt aliquem motum partium; nihil etiam potest pati ab agente naturali; non dividi, no uri, non torqueri, non stringi &c." (Fabri 1648, lib. 5, prop. 84, p. 193).

Remembering Fabri's remark in proposition 67 (Section 18.1 above) that in contrast to this description of Christ's passive existence in the host, a primary non-modal accident is "in a state of impenetrability" and thus can actively "reach its end, for were it not connected to impenetrability, it could not be moved, touched, perceived, etc."; and by Fabri's own account of an "accidentless" subject, which "*esset frustra*"; would it not be the case that the substance of Christ lying "under the species" is in vain? Needless to say that Fabri – a Papal Penitentiary, and no doubt a firm believer – would never claim that Christ's body exists in the host "in vain"; however, if we also take into account the omission of the adverb *substantialiter* which appears in canon 1, it seems fair to conclude that Fabri considerably plays down the Real Presence, while emphasizing as much as he can the role of the accidents in the function of the sacrament. As we shall soon see, Fabri will take pains, in his *Physica* – in line with tendency to thus "downplay" the role of Real Presence – to in effect sterilize Christ's manner of subsistence from any physical meaning.

18.2 "Atomistic" Heresy

I am not the first to point out that Fabri's theory of the Eucharist fails to live up to seventeenth century Catholic or Jesuit standards. Carla Rita Palmerino has already asserted that Fabri's belief in extended non-mathematical indivisibles[43] contradicted a censure written already in 1608 which damned the proposition that "Christ exists in the Eucharist in a finitely multiplied manner, that is to say as many times as there are indivisibles of the quantity of the sacramental species, out of which indivisibles that quantity is composed".[44] Palmerino explains that "Fabri actually asserted that space and time were made up of indivisibles and that the continuum was composed of physical points which were subject to contraction and expansion", and emphasizes that these opinions "had been most frequently censured by the Revisors General in the first decade of the seventeenth century" (Palmerino 2003, p. 193).

Proposition 82 of book 5 (*De accidente*), discussing the manner in which Christ exists in the Eucharist (probably based on statement [*positio*] 2 quoted above, though Fabri does not say so explicitly), indeed seems to affirm Palmerino's assertion:

> Proposition 82: by that reproductive action, Christ exists under the species in such a way that under any physical minimum of the species He is wholly there, not only before, but also after the division of that physical minimum. But the physical minimum of a species

[43] Fabri's concept of a "physical instant", which is divisible "potentially extrinsically", and therefore is not a "mathematical" indivisible, has been discussed in Part II (Section 9.1). By the same token Fabri also rejects "mathematical points" and opts for extended, or "inflatable" space indivisibles – which he refers to, in proposition 82 of *De accidente* (discussed in this section), as "physical minima" (see Palmerino 2003, pp. 198–199).

[44] Palmerino 2003, p. 187; the original Latin text: "Christus in Eucharistia existit finities replicatus, scilicet toties quot sunt indivisibilia quantitatis specierum sacramentalium: ex quibus indivisibilibus quantitas illa componi" (ibid., p. 218).

> is that portion, or particle, which can certainly be further divided, to heterogenic [entities], i.e. to mixable entities [*miscibilia*], yet not to homogenic [entities], that is parts of the same mixture.[45]

It must be emphasized that according to Aristotle's theory of mixtures, a mixture – although ultimately composed of the four elements – is by its nature homogenous, or "homoeomerous". For example, each part of the human body, e.g. "its head, limbs, and torso", is "composed of homogeneous parts, such as bile, blood, bone, hair, flesh, lard, marrow, sinew, and so on. The theory of the mixture explains how the combination of the elements can produce a homoeomery like flesh" (Wood and Weisberg 2004, p. 682). A "minimum of species" therefore is no longer a homogenic substance, since it can only be further divided to its heterogenic constituents, the diverse elements (i.e. the *miscibilia*). Fabri immediately continues:

> This being supposed, the conclusion is obvious; for if the whole of Christ were under the particles, or points, of the mixable entities, there would be no reason why following a disintegration [of the Eucharistic species] He should cease to exist under them [i.e. the points of the "miscibilia": the elements], because Christ is reproduced only under the species, e.g. of the bread. Therefore He is wholly under a minimum of the species, on which it could be said, were the substance [of the bread] present, that it is really bread; but if a point of an element is assumed, e.g. of which bread consists, it cannot be said, separately, that it is bread; but only [when] it is connected with others; therefore Christ does not exist wholly under it separately, but jointly.[46]

Fabri then explains that Christ does not correspond to any individual "point of bread" (i.e. an isolated element), for "He corresponds also to other points, which make up that abovementioned minimum, in such a way that He is under an entire minimum adequately and totally, and exists only once with it, i.e. by a single action, or reproduction. Hence there are as many distinct reproductions [of Him] as there are physical minima of this kind".[47] Following the fact that Fabri's indivisibles (*minima*) are extended, and therefore are "finitely multiplied" within any given extension, the last sentence indeed amounts to an explicit contradiction of the 1608 censure mentioned by Palmerino and cited above.

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[45] "Propositio 82: Per hanc actionem reproductivam, Christus ita est sub speciebus, ut sub quolibet minimo Physico speciei totus sit, tum ante, tum etiam post eiusdem minimi Physici divisionem; est autem minimum Physicum speciei ea portio, seu particula, quae certe ulterius dividi potest, in heterogenea, id est, in miscibilia, non tamen in homogenea, hoc est in partes eiusdem mixti" (Fabri 1648, lib. 5, prop. 82, pp. 192–193).

[46] "Hoc posito patet conclusio; si enim Christus totus esset sub miscibilium particulis, seu punctis, nulla esset ratio, cur sub illis, resolutione facta, esse desineret, quia Christus tantum reproducitur sub speciebus v.g. panis, igitur totus sub minimo speciei, de quo posset dici, si adesset substantia, est vere panis; sed si assumatur punctum elementi, v.g. ex quo panis constat, non potest dici de illo seorsim, quod sit panis; sed tantum de illo cum aliis iuncto; igitur non est totus Christus sub illo seorsim, sed coniunctim" (Fabri 1648, lib. 5, prop. 82, p. 193).

[47] "Respondeo... totum Christum cuilibet puncto respondere, sed non tantum, cum etiam aliis punctis, quae praedictum minimum componunt, respondeat; ita ut toti minimo adaequate, & totaliter subsit, sitque tantum semel cum illo, id est per unicam actionem, seu reproductionem. Hinc tot sunt reproductiones distinctae, quot sunt huiusmodi minima Physica" (Fabri 1648, lib. 5, prop. 82, p. 193).

Furthermore, the decision of the *Ordinatio pro studiis superioribus* (1651) to not only condemn the composition of the continuum from indivisibles in general,[48] but also specifically reject “inflated points” as the constituents of the continuum,[49] reaffirms the continuous hostility of the Jesuit establishment not only to Galileans, Democriteans etc. but also to Fabri-style atomists.

It is worth mentioning that Fabri repeats this heretical statement in book 8 (*De loco*) of the *Metaphysica*. Speaking again about the mode in which Christ exists under the “Eucharistic species”, Fabri says:

1. He is wholly under single physical minima of the species (e.g. of the bread) by a single indivisible action by which all the parts of Him are copenetrated with any minimum and also one with each other.
2. Hence He exists under it [the minimum] indivisibly and penetrably. . .
3. The body of Christ is reproduced as many times as there are minima of species under which He exists, hence there are as many ubications, or actions,[50] which are terminated at the body of Christ as there are those abovementioned minima, whether they are united to each other or separated.[51]

In any case, it seems that Dennis Des Chene is not entirely correct in claiming that Fabri “did not oppose the ‘Democritean’ philosophy *tout court*, but because it was empirically inadequate and contrary, as far as the Eucharist was concerned, to Faith” (Des Chene 2001, p. 364). It rather appears that Fabri, holding his own “atomistic” (or at least corpuscularian) theory of matter, did indeed try (despite the clear hostile opinion of his order) to explain the Real Presence according to principles which could be regarded – and were, by the Jesuit authorities – as at least partly “Democritean”. Furthermore, even a cursory glance at the previous part (discussing Fabri’s adoption of conservation of rectilinear motion) utterly refutes the claim which has been raised by several historians – that the issue of the Eucharist deterred Fabri from accepting void and motion through it (see “Introduction” above).

[48]“Continuum successivum et intensio qualitatum solis indivisibilis constant”; *Ordinatio pro studiis superioribus (1651)*, prop. 25, in Pachtler 1887–1894, vol. III, p. 92.

[49]“Dantur puncta inflata ex quibus continuum componatur”; *Ordinatio pro studiis superioribus (1651)*, prop. 26, in Pachtler 1887–1894, vol. III, p. 92.

[50]For the meaning of “ubicatio” (more or less “absolute space”) see Section 14.1 above. Fabri regards both *duratio* and *ubicatio* as an *actio* (see Section 9.1).

[51]“Ex his non difficile explicari potest modus ille, quo Christi corpus est sub speciebus Eucharisticis: primo totum est sub singulis minimis physicis specierum panis v.g. per unicam actionem indivisibilem, per quam scilicet omnes illius partes cum minimo quolibet, atque adeo inter se compenetrantur; secundo hinc sub illo est indivisibiliter penetrabiliter. . . tertio, toties corpus Christi reproducitur, quot sunt minima specierum sub quibus est, hinc tot sunt ubicationes, vel actiones, ad corpus Christi terminatae, quot sunt praedicta illa minima, sive inter se sint unita, sive separata” (Fabri 1648, lib. 8, prop. 18, p. 342).

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Chapter 19
Physica: Solution of the Real Presence Problem

Dennis Des Chene remarks that Fabri's *Physica* is unusual among Aristotelian texts, for it "includes a proof of the existence of '*corporeum quantum*' ", and he also asserts that Fabri, clearly influenced by Descartes' theory of matter, nevertheless "emphasizes the impenetrability of body, not its extension" (Des Chene 2001, p. 364). Fabri's first book of the *Physica* is indeed called *De quanto corporeo*, and already the brief introduction to it reveals that Des Chene's second remark is as valid as the first one: Des Chene has pinpointed Fabri's first and foremost property of matter (i.e. impenetrability), and furthermore has importantly observed that the context with which we should compare Fabri's theory is no longer scholastic (or exclusively scholastic), but also – and perhaps even mainly – Cartesian. In this short introduction, Fabri promises to demonstrate the "primary affections" of bodies (which "are considered to be in a body before others are demonstrated concerning that body") such as "quantity, impenetrability, continuity, divisibility and so on". He also promises to explain the "essential concept of a body", "for nobody can deny that a body should be considered impenetrable before it is demonstrated to be heavy, hard or dense".[1]

19.1 The Importance of Impenetrability

Sure enough, immediately following this introduction the first definition – that of body (*corpus*) – involves impenetrability: "Definition 1: a body is a substance exacting (*exigens*) necessarily by itself (per se) impenetrability".[2] As we shall soon see,

[1] "Primarias corporis affectiones, in hoc primo libro, demonstramus; primarias voco illas, quae prius corpori inesse censentur, quam aliae de ipso corpore demonstrentur; sunt autem illae, Quantitas, Impenetrabilitas, Continuitas, Divisibilitas, &c. His adde essentialem corporis conceptum, quem hic etiam explicamus; nam nemini dubium esse potest, quin corpus impenetrabile supponatur, antequam grave, vel durum, vel densum esse demonstretur" (Fabri 1669–1671, tr. 1, lib. 1, p. 1; just before def. 1).

[2] "Definitio prima: Corpus, est substantia per se necessario exigens impenetrabilitatem" (Fabri 1669–1671, tr. 1, lib. 1, def. 1, p. 1).

M. Elazar, *Honoré Fabri and the Concept of Impetus: A Bridge Between Conceptual Frameworks*, Boston Studies in the Philosophy of Science 288,
DOI 10.1007/978-94-007-1605-6_19,

Fabri regards this basic property of "exacting impenetrability per se" as the main feature of a body, as the very "essential concept" of it which he had just promised to explain. The next important definition, definition 3, characterizes the entity which appears in the name of this book, i.e. the "*quantum corporeum*": "Corporeal quantity is that which necessarily is either connected, or exacts being connected, with impenetrability".[3] As for impenetrability itself, it is – by definition 5 – "a mode of extension by which something is said to be impenetrable", while an impenetrable thing is simply that "whose place cannot be occupied unless it moves away from it". Impenetrability is necessarily a mode, because it cannot be conceived without the object characterized by this mode, i.e. an impenetrable thing.[4]

Fabri's first hypothesis claims that "*corporeum quantum* exists", basing himself on our ability to touch things, which naturally stems from their impenetrability.[5] The first proposition proclaims the existence of "something impenetrable": if someone is wounded by a sword, or burned by fire, Fabri explains, "it is evident that he feels (*sentit*)", therefore it is evident that he has a sense organ, which could not function, i.e. be "impressed by affections", unless it were impenetrable (this is what Fabri previously claimed, in axiom 8).[6] This line of thought leads Fabri to form an interesting counterpart to Descartes' famous dichotomy between *res extensa* and *res cogitans*: "Hence", says Fabri in the corollary of the first proposition, "it is certain to a man, and also evident, that an impenetrable organ exists in him, as much as a soul, or a mind does". He continues to explain that as much as we can infer from the verb *cogito* that a *mens cogitans* exists (and here Fabri obviously follows Descartes), likewise we may also infer from the verb *sentio* that a "sense", or an "impenetrable

[3] "Definitio III: Quantum corporeum est, quod cum impenetrabilitate, necessario, vel coniunctum est, vel exigit esse coniunctum" (Fabri 1669–1671, tr. 1, lib. 1, def. 3, p. 2).

[4] "Definitio V: Impenetrabilitas est modus extensionis, quo aliquid dicitur impenetrabile. Illud autem est impenetrabile, cuius locus occupari non potest, nisi ex eo loco amoveatur... dicitur modus, quia impenetrabilitas non potest concipi sine impenetrabili, ut constat ex ipsis terminis" (Fabri 1669–1671, tr. 1, lib. 1, def. 5, p. 4).

[5] "Hypothesis I: Datur corporeum quantum. Haec hypothesis certa est Physice; tangis enim lignum, saxum, carnem, aquam, &c. Haec sunt corporea quanta..." (Fabri 1669–1671, tr. 1, lib. 1, hyp. 1, p. 4).

[6] "Propositio I: Datur aliquid impenetrabile. Probatur, si quis gladio vulneretur, vel uratur igne, sentit evidenter; igitur evidens est illum sentire... igitur certum est, affectionem illam imprimi, quam, vel per quam, sentit; igitur organo imprimi; quidquid enim imprimitur, alteri imprimitur; igitur certum est ipsum organum, tum ipsam affectionem esse... sed organum illud est impenetrabile, per ax. 8, igitur certum est dari aliquid impenetrabile" (Fabri 1669–1671, tr. 1, lib. 1, prop. 1, p. 7). In axiom 8 ("Organum sensus est impenetrabile, & affectio impressa, est corporea") Fabri remarks that "unless a sense organ were impenetrable, a division of parts of a continuum would not occur", and this division seems to be necessary since the action of each sensory organ involves some kind of "corpuscula" interacting with it (for example, concerning the tongue and the sense of taste: "... nisi enim lingua esset impenetrabilis, nullam affectionem corpuscula illa saporifera, ab humore diluta & delata, ipsi imprimerent"). Fabri adds that he has elsewhere (in his book *De homine*) thoroughly explained this point, i.e. why a sense organ must be impenetrable in order to function. Fabri 1669–1671, tr. 1, lib. 1, ax. 8, p. 6.

organ", exists. The big difference between the two Frenchmen is apparent, however, when Fabri bases the existence of himself not on the *cogito* he borrowed from Descartes, but on his own *sentio*.[7]

The centrality of impenetrability to Fabri's concept of matter is of course an old atomistic notion: according to Lucretius, the essential property of a body is "to oppose and to obstruct" other bodies,[8] while Gassendi – the foremost seventeenth century champion of atomism – also held impenetrability as the most important criterion of bodies.[9] This notion is also deeply opposed to Descartes' view, and intimately connected to an issue which has been extensively discussed in the previous parts: Fabri's adamant belief that void is a legitimate scientific concept; for the void, which cannot be created by man within the universe, actually exists outside it and can be produced by God anywhere He wishes. From Descartes' identification of matter with *res extensa*, it is obvious that in the absence of matter there can be no extension at all, therefore there is no ground to claim that a three dimensional space devoid of matter might exist.[10] However, we have seen that Fabri's notion of bodies (i.e. matter) involves *impenetrable* extension, so the absence of matter entails (for him and the atomists) not the absence of extension per se but only the lack of impenetrable extension, thus rendering non-impenetrable extension a perfectly legitimate concept.[11]

Having convinced ourselves how important impenetrability was to Fabri, it could be asked – returning to Fabri's definition of a body as "a substance exacting necessarily by itself impenetrability" – why Fabri did not adopt a more straightforward conception of bodies: why body was not simply defined by him as an "impenetrable substance"? And what in any case did he exactly mean by the expression "exacting impenetrability"?

To try to answer these questions, we have to address two issues: first of all, the main subject of this part, the theory of the Eucharist; secondly, Fabri's concept of quantity, which will be dealt with immediately afterwards.

Fabri makes it quite clear that the reason for using such an indirect identification between body and impenetrability is none other than the Sacrament of the Altar. Proposition 8 purports to explain the "concept & essence" of body and eliminates

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[7] "Hinc tam homini certum, atque evidens est, sibi organum impenetrabile esse, quam animam, seu mentem; nec minus ex hac propositione, vel ex hoc verbo, *sentio*, colligo, esse sensum, & organum impenetrabile; quam ex hoc, *cogito*, colligo, esse mentem cogitantem" (Fabri 1669–1671, tr. 1, lib. 1, prop. 1, cor., p. 7). In the second proposition, which rather strangely reiterates the first hypothesis ("Datur corporeum quantum"), Fabri says: "evidens est, me sentire, dum sentio. . . igitur evidens me existere; nam quod sentit, existit, ut perspicuum est" (Fabri 1669–1671, tr. 1, lib. 1, prop. 2, p. 7).

[8] "Officium quod corporis exstat, officere atque obstare" (*De rerum natura* [Lucretius 1992], 1.336).

[9] LoLordo 2007, pp. 110, 222.

[10] See *Principles of Philosophy*, part II, art. 16, in Descartes 1984–1985, vol. I, pp. 229–230 and Garber 1992, pp. 298–300.

[11] See also Section 14.1 above, where Fabri regards vacuum as a "mode of a capacity".

several possibilities before introducing the correct one. The fifth possibility eliminated is "actual impenetrability" – and the reason is the Eucharist: The concept of body "cannot be obtained by actual impenetrability because the body of Christ is actually penetrated by the impenetrable Eucharistic accidents, and also because all the parts of His body penetrate each other". In other words, if we were to identify a body with mere impenetrability, we would have to conclude that Christ under the species (who according to Fabri is "penetrated" by the impenetrable primary non-modal accidents, as we have learned in the *Metaphysica*) does not qualify at all as a "body". In any case, Fabri ultimately declares that "the concept of body must be obtained from an exigence of impenetrability; thus in order that a substance be a body, it necessarily exacts impenetrability".[12] Fabri is in effect repeating definition 1 quoted above, which claims that "a body is a substance exacting necessarily by itself impenetrability"; the difference between this definition (or concept) of body and simply asserting that a body is an impenetrable substance is that the former definition allows for miraculously suspending the normal result of "exigence of impenetrability" (i.e. actual impenetrability), thus enabling Christ in the host to be called a "body" despite the absence of impenetrability.

As I have just mentioned, the issue of quantity is closely connected to the concept of body, and therefore also to impenetrability; it is therefore now time to address this complicated topic.

19.2 The Division of Quantity

Aristotle's theory of substance – once you get used to it – is basically quite simple and straightforward. Of his ten "categories", the primary one of "substance", comprising inseparable "matter" and "form", and the secondary one of "quality", i.e. a physical property predicating substances – make perfectly good sense. However, this basic simplicity is gone when we examine the category "quantity", which belongs (like "quality") to the nine secondary "accidental" categories. On the one hand, as an "accidental" category, used (like quality) to predicate a substance, it plays a physical function; on the other hand it also fulfills a mathematical function, because according to Aristotle it is also the answer to the general question "how much" (*quantum*), and therefore to specific questions such as "how long is this line" etc:[13] the two meanings, physical and mathematical, more or less coincide in the case of three

[12]"Propositio VIII: Hinc facile conceptus, & essentia corporis explicari potest... Quinto non potest accipi ab actuali impenetrabilitate, tum quia corpus Christi actu penetratur cum accidentibus Eucharisticis impenetrabilibus, tum [quia penetrantur] omnes eiusdem corporis partes inter se... Sexto, itaque conceptus corporis debet, ab exigentia necessaria impenetrabilitatis; ita ut corpus sit substantia, necessario exigens impenetrabilitatem" (Fabri 1669–1671, tr. 1, lib. 1, prop. 8, pp. 8–9).

[13]*Categories* [Aristotle 1928], 4, 1b25–29; see also *Metaphysics* [Aristotle 1908], 5, 13, 1020a7–16. Similarly, the category "substance" evolves from the question "what?" and "quality" from "what kind/sort of?".

dimensional (spatial) quantity.[14] The dual role Aristotle gave to quantity did not help to clarify the concept; the existence of the term "extension" (*extensio*) often equivalent to the "physical" meaning of quantity and hence to the mathematical in the case of three dimensional quantity – has also failed to contribute to the lucidity of the whole issue; Fabri's eventual relegation of "internal quantity" to metaphysics, thereby providing a third role to quantity, would of course do nothing to improve this problematic situation.

Aristotle makes it clear that quantity constitutes a category entirely different from substance, and asserts that "length, breadth, and depth are quantities and not substances (for a quantity is not a substance), but the substance is rather that to which these belong primarily".[15] Thomas shares this view, and also emphasizes and expands Aristotle's initial claim that quantity is "the proximate foundation for the remaining attributes of material substances" (Lang 2002, p. 566), by maintaining himself that "it must be borne in mind that of all the accidents quantity is closest to substance. [. . .] For next to substance only quantity can be divided into distinctive parts."[16]

Probably more famous is Thomas's use of quantity (especially its distinctness from substance) to explain how the Eucharistic species remain after the consecration. In his *Summa theologiae* Thomas asks "whether in this sacrament the dimensive quantity of the bread or wine is the subject of the other accidents" and answers in the affirmative.[17] Thomas's basic claim, in a nutshell, is that because "the Body of Christ is present in the sacrament, not after the manner of 'quantity' (*per modum quantitatis*), but of 'substance' (*per modum substantiae*)"; therefore "its quantity, present merely *per concomitantiam*, must follow the mode of existence peculiar to its substance, and, like the latter, must exist without division and extension, i.e. entirely in the whole Host and entirely in each part thereof" (Pohle 1909). This is why we do not perceive Christ in the host as a normal corporeal quantity, extended and divided into parts: what we do perceive is the miraculously remaining quantity of the bread, which serves as a subject to all the properties of the bread.

The well known Nominalist anti-Thomist reaction – which in the words of Amos Funkenstein "aimed to an absolute transparency of the language of every science" (Funkenstein 1986, p. 57) – has deemed quantity (as well as extension, motion etc.) a "connotative" term, which does not refer to real singular entities, and is valid only insofar as it is "coextensive with a set of singular entities" (ibid.). The Nominalists, having denied that quantity is an independent category referring to anything "real" (beyond the substance or quality itself), and stressing that it only serves to signify

[14] Quantity, of course, does not have to be dimensional (time and motion are also considered to be continuous quantities, while numbers and vocal utterances are discrete quantities); and dimensional quantities naturally need not be spatial, e.g. lines and surfaces (*Metaphysics* [Aristotle 1908], 5, 13, 1020a17–32; Lang 2002, pp. 567–568).

[15] *Metaphysics* [Aristotle 1908], 7, 3, 1029a14–16; quoted in Lang 2002, p. 570.

[16] Quoted in Lang 2002, p. 573 (from Thomas's Commentary on *Metaphysics*).

[17] *Summa theologiae*, 3a, q.77, a. 2, in Aquinas 1964–1981.

that a substance or a quality has "part outside of part",[18] refused to accept Thomas's claim that the quantity of bread survives the consecration and serves as a subject to the other accidents: they simply argued that God can easily maintain the quantities of the sensible qualities which miraculously continue to remain.[19] Accepting only substances and qualities as "denotative" (i.e. real) entities, the Nominalists explained that every physical reality can have its own quantity associated with it, which God can preserve if He wills, so there is no need to assume the conservation of the substance's quantity. As Edith Sylla explains, unlike Thomas – who modifies (by his intricate view of quantity) natural philosophy to explain the Eucharist – "where natural philosophy is not applicable Ockham refers to God's direct intervention rather than assuming a modified physics".[20]

Jesuit scholars, as is well known, were deeply affected by the Nominalist criticism of Thomas, though in accordance with Loyola's famous *dictum* they obviously did not renounce his view altogether. Suárez, for instance, disagrees with the Nominalist claim that the quantities of the qualities alone can explain the Sacrament.[21] However, not only does Suárez report the best Nominalist arguments against Thomas's distinction between substance and quantity,[22] he specifically admits that "natural reason" (i.e. Thomas's philosophical argumentation) has failed to convince him regarding this distinction, and states that it should be after all accepted chiefly "on account of the mystery of the Eucharist".[23] Suárez's view was apparently shared by quite a few Jesuits; Hellyer observes that "Increasingly Jesuit philosophers, even prominent ones such as Suárez and [Rodrigo de] Arriaga, merely paid lip service to the Realist position while expressing approval for the Nominalist account".[24]

Jesuit philosophers were therefore highly influenced by the Nominalist attack on Thomism, but being unwilling to give up entirely the notion of quantity as a distinct reality, they preferred to modify it, by dividing quantity to two kinds, "internal" and "external":

[18] This is explicitly Ockham's view (Hellyer 2005, p. 97).

[19] Lang 2002, p. 586, n. 92.

[20] Sylla 1975, p. 363. Sylla concludes that Ockham's view implies the autonomy of natural philosophy (ibid.). However, Weisheipl estimates that "were it not for the Eucharist, Ockham would have denied absolute reality to every accident" – i.e. including qualities – and so would have admitted the absolute reality of substance alone; Weisheipl 1963, p. 329.

[21] Suárez argues that the impenetrability of the host cannot be explained by the individual quantities of the remaining *species*, and therefore it must be somehow related to the quantity of the original substance (Lang 2002, p. 586, n. 92).

[22] For example, that there is simply no observable effect whatsoever which requires such a distinction (Hellyer 2005, p. 97).

[23] "Atque haec sententia est omnino tenenda; quamquam enim non possit ratione naturali sufficienter demonstrari, tamen ex principiis theologiae convincitur esse vera, maxime propter mysterium Eucharistiae" (*Disputationes metaphysicae*, disp. 40, sect. 2, n. 8 in Suárez 1856–1878).

[24] Hellyer 2003, p. 33, n. 120.

> Later Scholasticism (Bellarmine, Suárez, Billuart, and others) tried to improve upon this [i.e. Thomas's] explanation along other lines by distinguishing between internal and external quantity. By internal quantity (*quantitas interna seu in actu primo*) is understood that entity, by virtue of which a corporeal substance merely possesses "aptitudinal extension", i.e. the "capability" of being extended in tri-dimensionaI space. External quantity, on the other hand (*quantitas externa seu in actu secundo*), is the same entity, but in so far as it follows its natural tendency to occupy space and *actually* extends itself in the three dimensions. (Pohle 1909)

Fabri indeed defines "internal" and "external" quantity along similar lines. In his *Physica* Fabri explains that three kinds of quantity exist: "corporeal quantity" (*corporeum quantum*),[25] i.e. the impenetrable three dimensions of any concrete object; "incorporeal quantity" (*incorporeum quantum*), the quantity of incorporeal objects such as angels; and a quantity "abstracted from matter", i.e. a mathematical quantity. Then he states that "corporeal quantity", which is the only kind of quantity discussed by him in this book (entitled indeed *De quanto corporeo*), is twofold, and consists of "external quantity", i.e. the "impenetrable extension itself", and "internal quantity", which is "the proximate root of the external, i.e. that by which something exacts the external".[26]

Later in his *Physica* Fabri asserts that external quantity, i.e. "the extension itself by which something is extended impenetrably" evidently exists,[27] and adds that "internal quantity also exists, because there is no 'second act' (*actus secundus*) – at least naturally, and barring a miracle (*citra miraculum*) – to which a 'first act' does not correspond connaturally", and since "external quantity exists, which is the 'second act', therefore also internal [quantity exists], which is the first act (*actus primus*)".[28] The expression *citra miraculum* is connected, of course, to the issue

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[25] The concepts "quantum" and "quantitas" seem to be almost identical, for "quantitas" is nothing but a "concrete" answer to the question "how much" (quantum), or that "by which something is said – or may be said – to be a quantum": "Definitio IV: Quantitas est, qua respondetur, vel responderi potest, in concreto, adiectivo, accidentali, ad interrogatum, quantum est; seu, qua aliquid dicitur, vel dici potest quantum." In any case, Fabri uses the two terms interchangeably, especially in definition 4 (Fabri 1669–1671, tr. 1, lib. 1, def. 4, pp. 3–4).

[26] "Hinc vides tria esse quantorum genera; nempe aliud est corporeum, id est, cum corpore, vel impenetrabilitate necessario coniunctum, de quo def. 3; aliud incorporeum, aliud abstractum a materia, id est, mathematicum... Porro In hoc libro tantum agimus de Quantitate Corporea... haec autem duplex esse vulgo dicitur, interna scilicet, & externa; illa est proxima radix externae; id est qua, aliquid exigit externam; externa vero est ipsa extensio impenetrabilis" (Fabri 1669–1671, tr. 1, lib. 1, def. 4, pp. 3–4).

[27] "Propositio III: Datur quantitas externa. Probatur, quia haec est extensio ipsa, qua aliquid impenetrabiliter extenditur..." (Fabri 1669–1671, tr. 1, lib. 1, prop. 3, p. 7).

[28] "Propositio IV: Datur etiam quantitas interna. Quia nullus est actus secundus, saltem naturalem, & citra miraculum, cui actus primus connaturalis non respondeat, ut patet ex terminis; sed datur quantitas externa, per p. 3, quae est actus secundus, igitur & interna, quae est actus primus" (Fabri 1669–1671, tr. 1, lib. 1, prop. 4, pp. 7–8). Concerning the phrases *actus primus* and *actus secundus* – appearing both in Fabri's text and in the quotation from the *Catholic Encyclopedia* above – see Section 7.2, Note 39 above.

of the Eucharist: God may suspend the internal quantity's "exigence" of external quantity, i.e. cause the "first act" not to result (as it normally would) in a "second act".

19.3 The Exile of Real Presence to Metaphysics

We have seen that Fabri in the *Metaphysica* does not find it difficult to account for the persistence of the accidents of the bread and wine (i.e. the Accidents problem), which of course agrees with the senses, and ventures to regard this as an opportunity to emphasize, or even glorify, his two non-modal accidents (and especially impetus). However, as far as Real Presence is concerned, Fabri saw fit to rather isolate (or even downplay) it, in order to deny it from contradicting in any way our sense data. It is time to see how Fabri handles the Real Presence problem in his *Physica*; as we shall soon find out his ultimate goal will be to transfer this problem to the area of metaphysics, and thus avoid the need to explain *physically* the phenomenon that defies not only all our sense data but also common sense.

The task of relegating the Real Presence problem to the realm of metaphysics is completed in the *Physics*, but it starts already in *De accidente* of the *Metaphysica*; and the starting point for this interesting undertaking is Fabri's notion of internal quantity. Proposition 40 of *De accidente* asserts that internal quantity "is not a physical accident, i.e. really distinct from a body, but rather metaphysical, that is to say a metaphysical property of all bodies; therefore it is distinct [from body] only formally".[29] The first step in Fabri's "scheme" then is to announce internal quantity as a "metaphysical" concept, rather than "physical". The remainder of this strategy is outlined in proposition 15 of *De quanto corporeo*, the first book of the first treatise of the *Physica*.

The especially long proposition 15 of *De quanto corporeo* – by far the longest proposition in this opening book of the *Physica* – maintains that "internal quantity of a substance is not really distinguished from that very substance".[30] This proposition actually repeats Fabri's statement from *De accidente*, which – having accepted that innate impetus and primary heat are the (non modal) accidents that remain following the consecration, and are therefore distinct from substance – rejects the distinctness of internal quantity, "which the Divine Thomas acknowledges".[31] In any case, proposition 15 repeats the important observation from the *Metaphysica*,

[29] "Respondeo quantitatem esse vel externam, vel internam; illa est, extensio, qua corpus, vel aliquod accidens corporeum impenetrabiliter extenditur, & haec est modus; interna vero est, quae huiusmodi extensionem exigit; & haec non est accidens Physicum, id est realiter a corpore distinctum, sed Metaphysicum, id est proprietas Metaphysica omnium corporum; ergo formaliter tantum distincta" (Fabri 1648, lib. 5, prop. 40, p. 180).

[30] "Propositio XV: Quantitas interna substantiae non distinguitur realiter ab ipsa substantia" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 16).

[31] Fabri 1648, lib. 5, prop. 64, p. 188.

that internal quantity is not a physical accident but a metaphysical one,[32] while the next step in Fabri's strategy is to identify the concept "body" with the concept "internal quantity". This is not a difficult task for Fabri, for we already have noticed that the essence of body consists in its "exigence of impenetrability", and also that internal quantity is "the proximate root of the external, i.e. that by which something exacts the external", whereas external quantity is nothing but actual impenetrability. Indeed proposition 14, searching for the "concept" of internal quantity, arrived at "exacting extension, by which an object would be extended impenetrably".[33] Now Fabri can safely claim that "things which have the same concept are not really distinguished; yet internal quantity and body have the same concept, therefore they are not really distinguished".[34]

Having argued for the statement "internal quantity of a substance is not really distinguished from that very substance", using (among other arguments) the quoted claim that the "concept" of both is the same,[35] Fabri enumerates – and answers – several objections to this statement. First of all, Fabri acknowledges the strength and centrality of the view which regards (internal) quantity as a separate category, and explains that the term that Aristotle, Thomas Aquinas, Suárez and many others have called "quantity" he himself defines as *external* quantity, "which I voluntarily concede is distinct from substance". However, Fabri explicitly denies (as in the *Metaphysica*) Thomas's claim that quantity is the subject of the Eucharistic accidents, and declares that "many of the recent [philosophers] will deny it", though he mentions no name.[36]

The second (long) objection deals exclusively with the problem of the Eucharist, and claims – contrary to Fabri's view – that "the internal quantity of e.g. bread

[32]"Respondeo quantitatem, internam scilicet, de qua tantum hic agimus, esse accidens Metaphysicum, seu proprietatem Metaphysicum corporis; hoc est non realiter, sed formaliter tantum distinctam, in quo nulla est penitus difficultas" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 21).

[33]"... conceptus quantitatis sit, exigere extensionem, qua res extendatur impenetrabiliter" (Fabri 1669–1671, tr. 1, lib. 1, prop. 14, p. 15). Compare this with the concept of body quoted in Section 19.1 (Note 12) above: "the concept of body must be obtained from an exigence of impenetrability; thus in order that a substance be a body, it necessarily exacts impenetrability".

[34]"Illa non distinguuntur realiter, quae habent eundem conceptum; sed quantitas interna & corpus habent eundem conceptum; igitur non distinguuntur realiter" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 16).

[35]At the beginning of *De quanto corporeo* Fabri restricts the discussion to concrete substances, so the terms "body" and "substance" are identical; see Fabri 1669–1671, tr. 1, lib. 1, def. 4, p. 3.

[36]"Obiicitur primo, tantam esse authoritatem illius sententiae, quae scilicet quantitatem internam a substantia distinctam adstruit, ut non levem falsitatis suspicionem contrariae conciliet... Sed profecto ad locum illum Aristotelicum, recte responderi potest, Aristotelem loqui de quantitate externa, non interna, ut patet ex ipsis terminis... Ad authoritatem divi Thomae, ibidem tantum contendit, accidentia Eucharisticis in quantitate subiectari, quod tamen multi ex recentioribus negabunt; praeterea loquitur tantum de quantitate externa, vel dimensiva, quod idem est, quam ego ultro a substantia distinctam esse fateor; idem prorsus ad authoritatem aliorum respondeo" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 18).

is included among the Eucharistic accidents, therefore it is separated from the substance of the bread".[37] Against this second objection, Fabri reiterates his explanation from the *Metaphysica* that the kind of quantity which indeed remains after the destruction of the bread is external, and that the primary non-modal accidents (as we recall, primary heat and internal impetus) "are in a state of body and therefore fulfill the role of a common subject", the inference being that there is no need for asserting that quantity (either internal or external) is the common subject.[38]

But still discussing the second objection, Fabri raises a problem which seemingly requires only a simple and short answer: obviously following the consecration some quantity of the bread remains, but according to Fabri's hypothesis none of it should remain, neither internal quantity, "because it is not distinct from the substance of the bread" (which becomes Christ), nor external quantity, which "since it is a mode, cannot exist separately", not even by a miracle.[39] It is important to emphasize that Fabri has already answered this question: both implicitly just a few sentences ago, when he claimed that the primary accidents of the bread serve as a "common subject" (i.e. common to every modal accident, including external quantity), and explicitly back in the *Metaphysica*.[40] Hence, Fabri could have simply answered that the internal quantity has indeed converted to the body of Christ, but the external quantity – like every other mode – adheres to the primary non-modal accidents; however, Fabri's answer digresses far beyond this expected answer:

> I answer that internal quantity, properly speaking, does not remain, as is clear from what has been said; something, however, remains that performs the function of internal quantity; namely those primary accidents, as far as by the reason of the Institution [of the sacrament] they are extended impenetrably. For since they perform all the sensible functions of the substance of the bread; that substance, as far as it is quantified, by internal quantity, behaves – in the order of our senses – as though it really remained; therefore those primary accidents, as far as they make that quantitative bulk – which can be affected, moved and mutated as though it really were the substance of the bread – [those accidents] may be said to be the internal quantity of the bread; not properly speaking and metaphysically, but equivalently physically.[41]

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[37] "Obiicitur secundo, quantitas interna panis v.g. inter accidentia Eucharistica numeratur, igitur a substantia panis est separata; igitur distincta" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 18).

[38] "Respondeo primaria illa accidentia... esse in corporis statu; quare subiecti communis munere defunguntur; ut explicatum est in *Metaph*. lib. 5 & 8" (Fabri 1669–1671, tr. 1, lib. 1, p. 19).

[39] "Dices aliqua quantitas panis est in Eucharistia, sed ex hac hypothesi nulla remaneret; non interna, quia non est a substantia panis distincta; non externa, quae cum sit modus, separata existere non potest; ergo nulla, quod dici non potest" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 19).

[40] Proposition 58 asserts that "ex hoc [Sacramento] habetur quantitatem externam, id est extensionem, qua res extenditur impenetrabilitatem, duritiem, humiditatem, ubicationem, opacitatem &c. esse accidentia modalia" (Fabri 1648, lib. 5, prop. 58, p. 186), while the following proposition (p. 196) adds: "Accidentia modalia adhaerent in hoc Sacrameno non modalibus".

[41] "Respondeo quantitatem internam proprie non remanere, ut patet ex dictis; remanet tamen aliquid, quod eius vices obit; scilicet accidentia illa primaria, quatenus ratione institutionis, impenetrabiliter extenduntur; cum enim defungantur omnibus sensibilibus muneribus substantiae panis; perinde se habet illa substantia, quatenus quanta est, quantitate interna, in ordine scilicet ad sensus nostros, atque si revera maneret; igitur accidentia illa primaria, quatenus faciunt illam molem

So, "properly speaking" – that is, metaphysically (*proprie & metaphysice*) – the internal quantity (body) of bread is transubstantiated to the internal quantity (body) of Christ. However, the primary accidents, which in the absence of internal quantity entirely fulfill the physical role of body (we have already seen that they receive a "state of impenetrability"), do remain, and thus could be considered to constitute physically (*aequivalenter physice*) the (metaphysically absent) original body of bread. Thus Fabri relegates the process of transubstantiation to the abstract realm of metaphysics, and comes very close to bluntly maintaining that from a physical point of view, the internal quantity of bread is not changed at all by this process. Fabri soon repeats his far reaching conclusion that physically the consecrated host remains the same:

> I conclude that it can also be said that the internal quantity [of the bread] in some way remains,[42] namely equivalently physically; certainly those primary accidents, the Institution being supposed, perform the role of corporeal quantity (*quantum corporeum*); i.e. the Institution itself exacts [them] to be impenetrably extended; and accordingly, they so to speak perform the duties of a common subject, or of internal quantity, in which other accidents are received, corrupted, intensified, and are subject to other changes (*motus*), to which they indeed would have been subject, had they been in a body.[43]

Farbri's bold statement is a natural consequence of his overall analysis: for internal quantity is a *metaphysical* quantity identified with body, therefore Fabri may claim that Christ's body exists under the species as an internal quantity only, i.e. "*proprie & metaphysice*", and although according to the "concept" (or essence) of internal quantity it should cause His external quantity (i.e. actual impenetrability), the "miracle of the Institution" prevents this actualization, or exigence.[44] Therefore we are left with the task of explaining the *physical* phenomena that we perceive – the impenetrability and all the other modal accidents of the bread still remaining, which as we recall are necessary "supposing the Institution".[45] Remembering the

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quantitativam, quae perinde pati, moveri, & mutari potest, atque si revera esset substantia panis, possunt dici quantitas interna panis; non proprie, & Metaphysice, sed aequivalenter Physice" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, p. 19).

[42] The reader should recall that according to Fabri Christ exists in the host *only* as an internal quantity.

[43] "Nono, colligo etiam posse dici, quantitatem internam, aliquo modo remanere, scilicet aequivalenter physice; nempe illa accidentia primaria, posita institutione, corporei quanti munere defunguntur; id est, ipsa institutio exigit, extendi impenetrabiliter; ac proinde quasi subiecti communis vices obeunt, seu quantitatis internae, in qua alia accidentia recipiuntur, corrumpuntur, intenduntur, aliisque motibus subiacent, quibus revera subiacerent, si corpori inessent" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, cor. 9, p. 23).

[44] "Quinto colligo, corpus Christi servare quantitatem internam, non externam, sub accidentibus Eucharisticis; nempe cum non extendatur impenetrabiliter, non habet externam, per prop. 9, habet tamen internam, quia cum habeat rationem corporis, haec exigit impenetrabiliter extendi; huic tamen exigentiae non fit satis, propter miraculum institutionis" (Fabri 1669–1671, tr. 1, lib. 1, prop. 15, cor. 5, p. 22).

[45] See Chapter 18, Note 2 above.

theory Fabri developed already in the *Metaphysica*, according to which the primary accidents “perform the role of body”, it is only natural that Fabri explicitly claims here in his *Physica* that to all practical purposes (i.e. “*aequivalenter physice*”) they are indistinguishable from the internal quantity of the bread, and therefore the physical behavior of the bread is indeed perceived to remain the same following the consecration. This can be seen as the climax of a process already implied, of highly emphasizing the “Accidents aspect” of the Eucharist (which contradicts Aristotle, but not our sense data) while “downplaying” Christ’s Real Presence, by in effect emptying it from any physical meaning. It seems fair to conclude that Fabri shrewdly used the concept of impetus by giving it such a significant role in his solution to the Accidents problem, which ultimately neutralizes the Real Presence as a physical factor.

In any case, by claiming that the internal quantity of the bread “in some way” – i.e. “equivalently physically” – remains the same, Fabri in fact sterilizes any physical aspect within the process of Transubstantiation, thus fully assigning it to the higher realm of metaphysics. This opinion – along with Fabri’s description of Christ’s existence in the host (see Section 18.1, Note 42 above) – seems not to be in keeping with the traditional view, common to Thomists and Nominalists alike, which agreed that “Christ is present in the Eucharist with all his essential and accidental properties” (Sylla 1975, p. 365); in the eyes of Suárez, for example, the “Eucharistic mystery [. . .] discloses the Body of Christ truly present *physically* and therefore with material quantity, yet lacking actual local extension”.[46] Furthermore, Fabri’s view apparently does not fully abide by the spirit of the Council of Trent, concerning the “Totality of the Real Presence”:

> By virtue of the words of consecration, or *ex vi verborum*, that only is made present which is expressed by the words of Institution, namely the Body and the Blood of Christ. But by reason of a natural concomitance (*per concomitantiam*), there becomes simultaneously present all that which is *physically* inseparable from the parts just named, and which must, from a natural connection with them, always be their accompaniment. . . Hence Christ is present in the sacrament with His Flesh and Blood, Body and Soul, Humanity and Divinity.[47]

19.4 Transubstantiation and Descartes’ Condemnation

As Feldhay explains, the insistence of the Council of Trent on the physical reality of Transubstantiation is for good reason. The Catholic Church in the period of the Council “wished to bring its identity into focus by emphasizing its function as an institution mediating between the [‘natural’ and ‘transcendental’] worlds” (Feldhay 1995, p. 87). This can explain why

[46] Lang 2002, p. 587. My emphasis.

[47] Pohle 1909; again, the emphasis on the word “physically” is mine. Additional research is required in order to determine more decisively whether (or to what extent) Fabri’s opinion should be considered as conforming to doctrine or not.

> The decree concerning the sacraments, like all the other dogmatic decrees, conceptualized the connection between the physical, mundane world and the transcendental one. The sacrament conceived as a real act of transmission of grace and the emphasis on the cooperation between the human will and grace embody this connection. (Feldhay 1995, p. 82)

Fabri, living in a different era, by which the success of the Counter-Reformation had abated the fear from Protestant ascendancy and had helped to fortify a secure Catholic identity, preferred instead to neutralize the problem of the Eucharist as a physical issue already at the beginning of his grand physical work. It seems that Fabri – perhaps anxious concerning his scientific, rather than religious, identity – seized the opportunity presented by his unusual solution to the Accidents problem (i.e. impetus and heat) and the old debate on quantity to relegate the Real Presence problem to metaphysics, and thus ensure the autonomy of physics. In any case, it is highly important to emphasize that although the Council of Trent did take upon itself to organize Catholic Dogma vis-à-vis the Protestant Reformation, it refrained from establishing a binding philosophical explanation of the Eucharist, and thus enabled "a fair degree of latitude in the first half of the seventeenth century with respect to the metaphysical issues that provided the foundations for explanations of the Eucharist" (Ariew 1999b, p. 153). The only issue closed to debate among Catholics was Transubstantiation itself, since the Protestants either abandoned Transubstantiation in favor of Consubstantiation (Lutherans), rejected the Real Presence of Christ in the Eucharist altogether (Zwinglians), or adopted some kind of a compromise between Luther and Zwingly (Calvinists).[48]

Indeed, Fabri himself issued (in 1660) a "censure" of Descartes' explanation of the Eucharist that found it irreconcilable with Transubstantiation and which is said to have played a role in Descartes' post-mortem condemnation in November 1663. Descartes' biographer, Adrien Baillet, was the first to publicly explain the decision to put most of Descartes' works on the *Index librorum prohibitorum* by the "intrigues of a certain author" – namely Fabri.[49] Baillet provides no evidence for this accusation, and it is hard to determine whether – or to what extent – Fabri's activity (including this censure) contributed to this unfortunate decision.[50] Lukens claims that Gaston Sortais, in his study of Cartesianism among the French Jesuits, "thinks that if Fabri was involved, it was only to insist that the condemnation be softened by the phrase *donec corrigantur* (until they be corrected)".[51] However, Sortais only remarks that the qualification *donec corrigantur* means that Descartes' philosophy is composed both of good (*bons*) and bad (*mauvais*) elements, and that this is how Fabri regarded it; his point is that the only possible motive that

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48 Vollert 1967, p. 259.

49 Baillet 1691, vol. 2, p. 529. A contemporary Benedictine, Dom Antoine Vinot, raised – already early in 1664 – a similar suspicion concerning Fabri in a letter to Clerselier, the editor of Descartes' works; McClaughlin 1979, pp. 571–572.

50 C. F. Fowler, writing in 1999, reports "the lamentable fact that the official papers of the now defunct Congregation of the Index, as part of the archive of the former Holy Office, still remain inaccessible even to scholars"; Fowler 1999, p. 10.

51 Lukens 1979, p. 24.

Fabri – "a broad-minded person and a friend of free discussion" (*un esprit large et ami de la libre discussion*) – could have had for intervening was Descartes' explanation of the Eucharist, not his pure philosophy (Sortais 1929, p. 50). It should be added that in any event there was no consensus among contemporaries that the conditional addition *donec corrigantur* did signify a "softening" of Descartes' condemnation.[52]

Fabri seems to have found Descartes' solution of the Accidents problem satisfactory (Lukens 1979, p. 23), but was clearly not happy with his handling of the Real Presence problem: the Jesuit claimed that Descartes' contention that the Real Presence consists of merely a "union" between the consecrated bread and Christ's soul could by no means account for the change of substance necessary for the doctrine of Transubstantiation.[53] It could be asked, of course, whether Fabri's own explanation of Transubstantiation – both the relegation of the problem to metaphysics, as well as the enthusiastic solution of the Accidents problem (relying on impetus), which seems to smack of Consubstantiation[54] – should be considered much more "pious" than Descartes'. Be that as it may, clearly the persecution of Cartesianism over the issue of the Eucharist – which actually only began in 1663[55] – can hardly be explained in terms of doctrine alone. As Trevor McClaughlin observes, "had the political and religious atmosphere been a more congenial one, the disputes over Descartes' interpretation of the Eucharist would have been no more than academic" (McClaughlin 1979, p. 573).

Antoine Arnauld, the indefatigable supporter of Descartes, angrily responded to Descartes' 1663 condemnation, and his bitter response serves not only to prove the arbitrariness and injustice of this condemnation,[56] but also highlights an important aspect of Fabri's theory of accidents (or forms). Although Arnauld was certain that the Jesuits – including Fabri himself – were to blame for the 1663 condemnation,[57] he nevertheless commended two "eminent Catholics" – one of them Fabri (the other was the Minim Emmanuel Maignan) – who despite the sharp 1624 condemnation

[52] The prominent Jansenist Antione Arnauld, an ardent supporter of Descartes, found no comfort in this qualification, and "pointed out that in practice there is no difference between an absolute prohibition and a conditional one, as long as the censors fail to nominate and correct the supposed errors" (Fowler 1999, p. 14).

[53] Fabri argues in his censure that if God were to unite, for instance, a stone with a human soul, "the entity of the stone would remain the same (sic, si Deus uniret animam hominis saxo, maneret eadem entitas saxi)"; Sortais 1929, p. 51, n. 2. See also Armogathe 1977, p. 75. For Descartes' views which would ultimately raise this storm see Descartes' letter to Mesland from 9 February 1645, in Descartes 1970, pp. 155–159.

[54] As explained in the end of Section 18.1 above.

[55] For example, in 1673 the teaching of Cartesian philosophy was forbidden by the king and the University of Paris, and in the following years some prominent religious figures published anti-Cartesian treatises; Nadler 1988, p. 238.

[56] Arnauld defiantly asked the Roman censors why they were so eager to put Descartes' works in the *Index*, and yet failed to condemn Gassendi, who was insolent enough to try and disprove (Descartes'!) proof for the immortality of the soul (Nadler 1988, p. 239).

[57] Ariew 2003, p. 184; Nadler 1988, p. 239.

of anti-Aristotelian philosophy (issued by the Parlement of Paris) rejected substantial forms.[58] Fabri, such an ardent supporter of *accidental* forms (especially impetus and heat), has indeed relegated a dubious manner of existence to *substantial* forms. Fabri's view became known to Arnauld through the Jesuit's *Tractatus duo quorum prior est de plantis et De generatione animalium, posterior De homine* (Paris, 1666), and Arnauld saw fit to emphasize that this work was dedicated by Fabri to the General of the order.[59] Fabri repeats this opinion in his *Physica*. He claims there that any "corporeal form" – that is, any substantial form, except for the human soul – is not an "absolute entity" (*ens absolutum*), but only a "respective entity" (*ens respectivum*), which is "a kind of a relation, or mode of substantial being" (*quasi relatio*, *seu modus essendi substantialis*), and therefore cannot exist without matter. To the objection that accidental forms do exist without subjects – "as is clear by the Eucharistic species" – and therefore "all the more so" (*multo magis*) substantial forms, Fabri responds that in contrast to impetus and heat, which are indeed absolute entities, a substantial form "is not an absolute entity... but a kind of a substantial mode, or some *respectus*".[60] Fabri repeats this observation yet again in his letters to Pardies, where – as Paul Blum has observed – Fabri in effect degrades substantial forms "ontologically to a kind of 'viewpoint' ", an interpretation which is described by Blum "as a very modern, post-Kantian one, where concepts like nature and substance are held to be concepts of mere reflection, tools of interpretation of the world, or *Reflexionsbegriffe*".[61] Fabri's view concerning *substantial* forms has been indeed considered novel and innovative not only by historians and contemporaries, but also – alas – by the Jesuit authorities.[62] It must be reemphasized, however, that Fabri's view towards *accidental* forms is of course anything but post-Kantian, and more-or-less conforms with Jesuit authority.[63]

[58]Nadler 1988, pp. 239–241; Ariew 1999a, p. 179. Nadler and Ariew rely on a text called "De la persécution du Cartésianisme en France", which appears in the writings of Victor Cousin but was actually written by Arnauld (Nadler 1988, p. 240, n. 30). Arnauld wanted to demonstrate that it was by no means impossible to hold (like Descartes) fundamental anti-Scholastic principles and yet remain loyal to Catholic Dogma.

[59]Cousin 1838, vol. 2, p. 192 (see also previous note).

[60]"Propositio LXIX: Hinc forma substantialis materialis, sine forma esse, vel existere non potest... igitur cum omnis forma corporea, sit ens respectivum, imo quasi relatio, seu modus essendi susbtantialis, non mirum est, si extra materiam existere non possit. Dices, forma accidentalis esse potest sine subiecto, v. gr. calor, impetus, ut constat ex speciebus Eucharisticis; igitur multo magis forma substantialis. Resp. negando consequentiam, quia calor & impetus sunt verae entitates absolutae... at vero forma substantialis corporea, non est entitas absoluta... sed quasi modus substantialis, seu quidam respectus" (Fabri 1669–1671, tr. 5, lib. 1, prop. 69, p. 43).

[61]Fabri 1674, p. 53; Blum 1999, p. 244.

[62]One of the condemned propositions in the *Ordinatio pro studiis superioribus* of 1651 maintains: "Mixta etiam corpora, excepto homine, non habent propriam formam substantialem"; *Ordinatio pro studiis superioribus (1651)*, prop. 19, in Pachtler 1887–1894, vol. III, p. 91. In 1678, following a strong anti-Cartesian "reaction" in France, a similar proposition was condemned by French Jesuits (Ariew 1999b, p. 142).

[63]It does not entirely conform to Jesuit directives, since as mentioned above (end of Chapter 17) regarding impetus as a non-modal accident (let alone employing it to "save" the Accidents

The relative flexibility of the Council of Trent, attested by the refusal to clearly define the term "species" (see beginning of Chapter 18 above), is also manifested by its deliberate decision not to sanction either Scotistic or Thomistic explanation of Transubstantiation, and thus – in the words of a bishop who presided over one of its sessions – "make a declaration in terms so general that it could be accommodated to the sense of the two parties".[64] The result was inevitably a considerable variety of opinions concerning the details of Transubstantiation, even among Jesuits. Suárez, for instance, opts for the annihilation of the bread during Transubstantiation – supported by the Scotists – and regards this action as a *reproductio*; Bellarmine and John de Lugo, also supporters of annihilation, contend that Christ's body is made present in the host by *adductio*, a transfer from heaven that does not involve local motion; other Jesuits prefer the traditional Thomist view of *conversio*, according to which Transubstantiation does not mean any kind of destruction, but a pure and immediate change of substance effected by God (Vollert 1967, p. 260). Fabri himself conveys a view similar to Suárez's, and regards Transubstantiation as a *reproductio* which does involve the destruction of the bread's substance.[65] It may be the case that this relatively relaxed attitude towards the Eucharist – prevailing at least before the Descartes affair erupted – enabled Fabri both to exploit the Accidents problem in order to support his theory of non-modal accidents and even aggrandize them (especially impetus), and to transfer the issue of Real Presence from physics to metaphysics, thus keeping physics free from having to deal with such matters of faith that defy common sense, not to mention mid-seventeenth century experimental science.

19.5 "Prudent Infidels"

A fascinating additional piece of evidence for Fabri's wish to release physics – the science of "natural effects" – from the difficulty presented to it by the Real Presence (without denying, of course, this Article of Faith) can be found in his preface to the *Physica*. Fabri explains here (as well as elsewhere – see, e.g., Section 4.2) that the "principal goal" of physics is to "reduce natural effects to their causes by demonstration", and that in order to achieve that goal we should first of all establish "regarding any effect what it is, and this by a certain and proven experiment, having applied a certain sense in a proper way and without error"; then, continues Fabri, we ought to "integrate", or "refresh", on the basis of what we are "physically" certain about concerning that effect, "what it really is". However, Fabri emphasizes that the certainty by which that effect can be known to us is only "physical, not geometrical;[66]

problem) must have been deemed at least somewhat dubious. Further research is required to check out this interesting point.

[64] Schmaltz 2002, p. 40, n. 52.

[65] Fabri 1648, lib. 5, prop. 82, pp. 192–193 and prop. 85, p. 194. See also Section 18.2, Notes 45, 46 above.

[66] "Geometrical" certainty is equivalent to "metaphysical" (i.e. absolute) certainty.

i.e. it cannot surpass the certainty of our senses". Fabri concludes that "physical certitude" is provided when we establish something "by a sense correctly applied and without error", and we do so "very prudently, as long as nothing else stands in the way, and no superior reason persuades" us otherwise.[67]

Fabri immediately invokes the issue of the Eucharist:

> For example, when I eat bread, i.e., when I feel affected by such a taste and other senses, I prudently assert that it is bread, and I am certain physically. And yet I am deceived in the Sacrament of the Altar, but by an eminent miracle. Therefore I would assert very imprudently that the consecrated divine host is bread; since I know, by a superior reason given by certain faith, that there is not any substance of the bread in there: an infidel, however, who never accepts anything of that mystery, would prudently judge, that there is bread in that place.[68]

Fabri then conveys his sorrow over the infidel, who in the absence of God's grace fails to perceive the higher (metaphysical) truth and recognize the presence of Christ in the consecrated host. However, Fabri chooses not to berate him for his ignorance, but rather remarks – in accordance with his demand to distinguish between "physical" and "metaphysical" knowledge – that the infidel "prudently" judges that what looks, smells and tastes exactly like ordinary bread is indeed nothing but bread.

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[67] "Hic enim praecipuus est Physicae finis, ut effectus naturae ad suas causas demonstratione reducat; id est, illorum causas demonstret; quod ut praestare valeam, statuo ante omnia de quolibet effectu, quod sit, idque certo ac probato experimento, applicato scilicet aliquo sensu, ut par est, eoque minime vitiato, sed integro, quo de tali effectu certus sim physice, quod revera sit... Illa porro cognitio, qua effectum illum esse cognosco, certa quidem est, sed Physice, non geometrice; id est, non superat sensuum nostrorum certitudinem... unde physica certitudo in eo posita est, quod ex sensu recte applicato & minime vitiato, aliquid esse, statuam, idque prudentissime, dum nihil aliud obstat, & nulla superior ratio rem secus esse persuadet" (Fabri 1669–1671, "auctor lectori", par. 2).

[68] "v.g. dum panem comedo, id est, dum ita gustum et alios sensus affici sentio, prudenter assero, panem esse, & physice certus sum; fallor tamen in Sacramento altaris; sed per insigne miraculum; unde imprudentissime assererem, divinam hostiam consecratam panem esse; cum per superiorem rationem a certa fide petitam, habeam, nullam ibi esse panis substantiam. Infidelis vero, qui nihil unquam de hoc mysterio accepit, prudenter iudicaret, ibi panem esse" (Fabri 1669–1671, "auctor lectori", par. 2).

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Conclusion

This book has confronted the influential contention of Anneliese Maier that Fabri used the medieval concept of impetus to fight Galileo's and Descartes' "New Science" (especially the "mechanics of inertia"). Part III has shown that Fabri carefully reconstructed the old concept of impetus, using tools which might appear at first sight to be scholastic obscurities, thereby cunningly assimilating (rather than fighting) some key principles of early modern science. He characterized the causality between impetus and motion as formal (rather than efficient), and insisted that impetus brings about motion not by producing (*producere*), but by exacting (*exigere*). This *prima facie* meaningless scholastic characterization, which in fact renders impetus unexhausted while causing motion – together with his definition of impetus as necessarily *determinatus*, i.e. acting exclusively along a straight line – enabled him to easily adopt the important principle of Conservation of Rectilinear Motion (CRM). As Part II has revealed, Fabri also used his distinction between influence *ad intra* and *ad extra*, and once again formal causality, to endorse another key principle of classical mechanics: the universal velocity of falling bodies in the void. Furthermore, his strange definition of time (actually discrete but potentially continuous) served to substantiate his claim that his discrete analysis of free fall (a mirror image of Galileo's continuous analysis) converged (under the assumption of tiny instants) to Galileo's odd-numbers rule.[1] Fabri's implementation of CRM in his discrete analysis of free fall[2] proves that for him, this principle is not a mere abstract notion occurring only in an imagined universe (emptied by God). It also contributes to the coherency of his general physical scheme, which I have defined as an "inertial framework", clearly expressed in an anti-scholastic tendency to implement physical analyses in the void and thus abstract them from air resistance. Hence, despite the obvious falsity of Duhem's contention that the medieval concept of impetus brought about inertia, it was not only possible for post-Galilean Aristotelians to employ impetus for assimilating CRM, but such an assimilation did in fact take place – proving the flexibility and potential of this allegedly dogmatic

[1] See also the Appendix "The Proof of Convergence to Galileo's Law of Fall".

[2] Theorem 13 of the second book of the *Tractatus physicus de motu locali* (discussed above in Part II, Chapter 8).

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and backwards notion, which Koyré regarded as so detrimental to the development of mechanics. Indeed, Rivka Feldhay's interpretive strategy of a "dialogical" approach between the New Science and Jesuit scientists proves, at least in Fabri's case, more adequate and fruitful than the "dichotomic" approach inaugurated by Maier.

No less important than Fabri's remarkable efforts to assimilate "cutting edge" key concepts is his willingness to harshly criticize the Aristotelian tradition which stood against these subversive notions – a criticism that has also been ignored by historians. Fabri flatly dismissed Aristotle's staunch rejection of the void (and the possibility of motion in it), and while doing so, incorporated into his physics two of the "paradoxes" which (according to the Stagirite) followed from the assumption of vacuum: the universal velocity of bodies (in the void) and CRM (see Section 14.3 above). Regarding free fall, Fabri bluntly accused Aristotle of failing to investigate acceleration, ridiculed the speculation (raised by Aristotle in *De caelo*) that the reason for natural acceleration might be the medium in which the body falls and discredited the simple proportions which Aristotle had proposed concerning falling bodies (e.g. the dependence of rate of fall on weight). Fabri also rejected the Aristotelian concept of levity, recognizing only absolute gravity (which amounts to "internal innate" impetus) as a key property of heavy bodies. He explicitly aligned himself (in the context of rejecting levity) with the physical tradition established (in his opinion) by Archimedes and adopted by Galileo, Torricelli, and others, including fellow Jesuits. Fabri took seriously his own declaration – raised while rejecting Aristotle's absolute levity – that "there is nothing wrong in deviating from Aristotle if either a manifest experience or an evident argument compels" us to do so (see Chapter 7 above). Furthermore, Baldini's assertion – that although Jesuits accepted (at least in part) Galilean kinematics, this acceptance had very little impact on their natural philosophy – obviously cannot be applied to Fabri (Baldini 1999, p. 266).

Fabri's striking open-mindedness, so much at odds with the general impression of him as merely "a spokesman for a very old tradition" (Lukens 1979, p. 260), or "the Advocate of Lost Causes" (ibid., p. 261), has not been entirely ignored by historians. Constance Blackwell called attention to Fabri's *Euphyander, seu vir ingeniosus* (1669), a treatise advocating the free use of reason and forbidding surrender to authority. In this work Fabri urges Euphyander, a fictitious young student, not to "swear by the words of the master unless truth is the master; nor should he by the same token be bound to the Thomists or the Scotists; let all his friends be lovers of truth... Let Euphyander maintain freedom of thought, let him enslave himself to no party lest he be forced to serve error, let him remain always in that state in which he may freely judge about the truth of a subject that is proposed, in brief let him surrender to reason and its demonstration alone".[3] In this book I have shown that

[3] "...iurare in verba magistri non debet, nisi veritas ipsa magistra sit; nec Thomistis, nec Scotistis plus aequo adductus esse; amici omnes sint veritatis amatores... Itaque Euphyander libertatem animi retineat, nulli parti se mancipet, ne aliquando errori servire cogatur; in eo semper statu sit, in quo de rei propositae veritate libere iudicet; uni rationi det manus, eique demonstrativae"

Fabri indeed practiced what he preached within this moving panegyric to freedom of thought, rather than being a mere representative of the Inquisition or a blind follower of Loyola's instruction to "believe that the white I see is black, if the hierarchical Church so defines it".[4]

However, it is also important to remember that in Fabri's case, openness and flexibility did not entail a wholehearted adoption of the New Science. I have emphasized that although the principle of CRM itself was more deep-rooted in Fabri's thought than in the theories of Galileo (who never explicitly formulated it) or other New Science pioneers (who generally opted for the conservation of both rectilinear and circular motions), Fabri's "inertial thinking" is nevertheless still far from classical physics. This is an inevitable conclusion of Fabri's theory of projectiles, that rejected the parabolic trajectory (along with superposition) in favor of a "hypothesis" which claimed that horizontal projectiles (and even those projected downwards with an angle) must gradually lose their speed. Fabri, insisting that air resistance has almost no effect on projectiles, did not realize that this hypothesis, although true for many observed projectiles (especially fast ones), was entirely false in vacuum. He did adopt in his theory of projectiles a basic "inertial framework", expressed by his willingness to assume motion in the void and by his explicit formulation of CRM,[5] but he remained loyal to the basic Aristotelian ideology of *scientia*, that regarded physics as a discipline which should reduce "sensible effects" to their causes. Fabri accordingly rejected Galileo's parabola, a trajectory never actually observed in a standard environment, and remained loyal to the scholastic tradition, which regarded violent motion as necessarily being destroyed by gravity, unless they are in the same direction.

The same loyalty to "sensible effects" caused Fabri to adopt Galileo's (observable!) experimental results on the one hand (by proving the genuine convergence of his own discrete analysis to Galileo's proportion $s \propto t^2$), but to reject Galileo's approach to the nature of the continuum on the other hand. Fabri's attitude, reflecting the views of Aristotelians and *novatores* (e.g. Descartes) alike, is exemplified in his rejection (or lack of understanding) of Galileo's principle of one-to-one correspondence. This rejection caused Fabri (and many of his contemporaries) to erroneously regard a body falling perpendicularly as passing through fewer degrees of velocities than a body descending along an inclined plane (see Section 10.1 above). Furthermore, Fabri's ideal of "sensible effects" meant that while he adopted CRM, he refrained – contrary to Descartes before him and Newton after him – from depicting it as a fundamental law of nature.[6]

(Fabri 1669, lib. 2, cap. 1, pp. 61–62; quoted in Blackwell 1995, p. 57). This treatise also openly recommends reading Copernicus, Galileo, Kepler and Boyle (Blackwell 1995, p. 73).

[4] These are the opinions of Dora Shapley and William Ashworth on Fabri (see "Introduction" above).

[5] Fabri emphasized that in the absence of gravity, a projectile "would obviously move along a straight line with constant motion".

[6] In this Fabri followed in the footsteps of Galileo's disciples, Cavalieri and Torricelli (see Koyré 1978, pp. 240–241).

In trying to assess Fabri's CRM concept, it is worth consulting the comparison offered by Alan Gabbey between Descartes' and Newton's notions of inertia, in his article "Force and Inertia in the Seventeenth Century: Descartes and Newton". Gabbey identifies three points of similarity between Newton and Descartes, which might be also relevant to Fabri's view:

(a) A clear rejection of the older Aristotelian view of motion as a process, its place being taken by the *status* conception.
(b) A complete "freedom from the tyranny of the circle" (in Gabbey's words), which dominated Aristotelian thinking and still held its grip on the dynamical thinking of Beeckman, Gassendi and even Galileo.
(c) The identity of description concerning the behavior of a body in the absence of impediments (Gabbey 1980, p. 291).

As Part III has shown, Fabri wholeheartedly adopts point (b): he emphasizes that circular motion is nothing but a "straight one impeded in single points", endorses in effect a reduction of curved motion to rectilinear motion, and accepts the important observation that a stone released from a sling will continue to move along the tangent. Fabri also adopts point (c), as is evident in his explicit assertion that if a horizontal projectile had no gravity (i.e. internal impetus) it "would obviously move along a straight line with constant motion" (Section 16.2).

Point (a) is more problematic. Gabbey means of course the dichotomy Koyré proposed between the Aristotelian "motion as a process" attitude and Descartes' concept of "motion as a state"; although Fabri described motion as a "respective mode", it is impossible – as Part I has shown – to ascribe to him the view of "motion as a state". In fact, in light of the dubious status allocated by Fabri to the concept of motion – a "*resultans, ut relatio*" which is not a "pure *ens*" (and therefore is not *producitur*, but *exigitur*) – it seems to me rather doubtful whether it is meaningful, or worthwhile, to try to determine to what extent Fabri's non-entity (or half-entity) of motion resembles Descartes' clear view of motion as a state. Be that as it may, E. J. Dijksterhuis points out that Newton's identification of inertial motion with a force – *vis inertiae* – is incompatible with the view that (straight and uniform) motion is a state, and concludes that if Koyré's proposed dichotomy "is to be maintained consistently, it thus appears necessary to consider Newton as not yet an exponent of classical mechanics" (Dijksterhuis 1969, p. 175).

As explained before (in the beginning of Chapter 12), an attempt to regard Fabri's CRM as equivalent to modern inertia would be in any case entirely erroneous and anachronistic. However, in assessing Fabri's philosophy of motion we could benefit from Descartes' important observation, that while the medieval *docti* constantly tried to explain why a projectile moves, "one should rather ask why it does not continue to move forever" (Chapter 13). The key issue whether the decay or the continuance of projectile motion should be explained can be used to delineate a borderline that differentiates between two conflicting conceptual frameworks, which can be denoted as "traditional" and "classical". The "traditional" framework – formulated by Aristotle, followed by the *docti* and still prevalent among many of

Fabri's contemporaries and even followers[7] – deemed physical objects as inherently tending to be at rest, and considered motion as *ipso facto* demanding a cause which must always maintain contact with the moved object; accordingly, this framework designated the medium or impetus (in some cases – both) as the cause responsible for the continuation of projectile motion. The "classical" framework, pioneered by Descartes and Galileo's disciples and accepted by us today, regards both rest and constant rectilinear motion as inherent, or natural, to physical bodies, and thus denies the need to assign a "cause" for each of them. These two conceptual frameworks would be inevitably regarded, by Thomas Kuhn's strict followers (who would define them as "paradigms"), as entirely incommensurable. Both of them relate to the same experiential phenomenon – a projectile continuing to move, after being thrown – but while the classical framework analyzes it using the principle of inertia (to be formulated by Newton as the first law of motion), there is no way the holders of the traditional framework (or paradigm) could ever be persuaded that such a principle is valid. In Kuhn's words, "a law that cannot even be demonstrated to one group of scientists may occasionally seem intuitively obvious to another" (Kuhn 1970, p. 150).

However, Fabri's case shows that in reality it is hard – perhaps impossible – to find real incommensurability in the realm of ideas. Fabri's philosophy of motion, as we have already seen, contradicts the traditional framework in many senses, but still does not embrace the classical one. Fabri "formally" belongs to the traditional conceptual framework, since he invokes impetus as the cause (or explanation) of any motion whatsoever, including projectile motion. Furthermore, his adoption of the natural/violent impetus dichotomy and rejection of superposition within his account of projectile are of course entirely anti-classical. However, by insisting that the key question which should be asked about projectiles is not their perseverance, but rather why violent impetus is destroyed, Fabri aligns himself on Descartes' side, against the *docti*. True, in Fabri's "thought experiment" that invokes a stone being thrown and then surviving the annihilation of the universe (Section 14.2), its resulting "inertial" motion is justified by a constant and unfailing impetus which continues to move it; but Fabri's manner of describing this consequence – depicting the stone as "retaining the same level of velocity" – smacks of the principle of sufficient reason. Taking into account Fabri's deep and explicit belief in the (potential) possibility of eternal violent motion (a view entirely opposed to the traditional framework), it is no wonder that he seems to take for granted the resulting "inertial" motion of the

[7] It still had followers even in the early 18th century; Healy 1956, pp. 75–78. In fact, as late as 1706, the following Cartesian ("inertial") propositions were prohibited by the Fifteenth General Congregation of the Jesuit order: "6. Modes or accidents, once produced in a subject, have no further need of any cause whatever to conserve them by positive action; rather, they should last until they have been destroyed by the positive action of some external force. 7. To believe that matter has lost some of the quantity of motion first impressed upon it by God, would be necessarily to suppose a changeable and inconstant God" (Healy 1956, pp. 29, 313; Healy's translation from Latin).

stone, according to his CRM principle, and insists (like the moderns) that the interesting question is not why a projectile continues to move, but why it stops. It is no coincidence, in this context, that both Fabri and Descartes consider this inertial consequence to be essentially guaranteed by God. Furthermore, Fabri does not regard rest as equivalent to straight and constant motion, but by accepting linear impetus only, by emphasizing the inherent linearity of impetus (and consequently motion), and also by regarding non-linear motion as nothing but "impeded" straight motion – he again distances himself from the traditional framework and advances towards the new one.

Certainly, Fabri's *answer* to this key question concerning projectiles – formulated by him as "why violent impetus is destroyed" – attaches him again to the traditional framework. Fabri himself presents his rejection of the Galilean explanation for this destruction (namely, air resistance) – in favor of an Aristotelian *frustra* mechanism, triggered by gravity – as contrary to the teaching of "Galileo's followers". This mechanism, which conveys an Aristotelian teleological sentiment, is considered by Fabri as better accounting for the real trajectory of a projectile than Galileo's symmetrical curve, which is not observed *de facto*. However, the future development of physics not only proves this solution to be entirely erroneous, but also reveals that it is a dead end. It was the acknowledgement of the gap between theory (formulated in a void) and practice (so much affected by air resistance) which led Galileo's successors – "the most acute mathematicians", in the words of A. R. Hall – to be "no longer interested in the parabolic theory, which had been fully worked out" and to turn to the analysis of air resistance, using the gradually developing tools of calculus and thus promoting mathematical mechanics.[8] Unlike the parabolic theory, Fabri's solution – in retrospect serving to sweep the difficult (but highly important) problem of air resistance under the carpet – was far from being (in Kuhn's terms) "sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve" (Kuhn 1970, p. 10).

In summary, Fabri's mechanics cannot be regarded as positively contributing in any meaningful way to the development of physics from Galileo to Newton. However, Fabri's physics is important as exemplifying a candid Jesuit attempt to remain up to date and yet not relinquish tradition: his concept of impetus could be regarded as a kind of a "bridge" between conceptual frameworks, by which Fabri could present significant advancement towards a new mechanical way of thinking, and at the same time remain (from several important respects) loyal to the old system. The Jesuits indeed have been recognized as "bridge builders", or "cultural mediators", not only between physical conceptual frameworks, but also "between the world of politics and the church establishment, between the secular and the regular clergy, and between non-Catholics and Catholics".[9] Furthermore, the part

[8]Hall 1952, p. 127. The "most acute mathematicians" to whom Hall refers are mainly Huygens, Gregory, Wallis and of course Newton.

[9]Feldhay 1995, pp. 128–131 (the quotation appears in page 128).

discussing Fabri's theory of free fall (Part II) emphasizes that Fabri's purely kinematic analysis – incorporating Galileo's crucial principles of universal speed of fall in the void and $v \propto t$, and ultimately converging to Galileo's odd-numbers law – "involves deliberately eliminating impetus, the alleged cause of free fall, as a factor which has any effect whatsoever on the way a body falls" (Section 11.2). Indeed, having incorporated CRM and a kinematic analysis of free fall, Fabri seems no longer to have needed the concept of impetus – in the same way that having accepted CRM, he seems to take for granted the "inertial" subsequent motion of a stone in an emptied universe. Therefore, Fabri's impetus might be more accurately regarded as actually nothing more than a scaffold, a means of assimilating major achievements of early modern science, only to be dismantled after doing its job – perhaps not unlike Wittgenstein's metaphor of the ladder, which having been constructed one must "throw away", or "surmount", in order to "see the world rightly" (Wittgenstein 1922, prop. 6.54).

The view I am suggesting here contradicts not only the attitude initially formulated by Maier (and henceforth adopted by many other historians) that Fabri's impetus should be seen as a means of *attacking* (rather than *assimilating*) the New Science. It is also totally incompatible with Fabri's own view, according to which impetus is a sort of a *deus ex machina* for understanding the universe, on which "not only motion itself but also the whole of physics depends" (Chapter 1). However, Fabri's impetus simply fails as a meaningful physical explanation. Impetus is allegedly the (formal) cause of motion, but by connecting it so intimately with the principle that whatever is "in vain" (*frustra*) is destroyed, Fabri turns impetus into an *a posteriori* object, rather than a physical explanatory concept. We can easily recognize this characteristic in his account of the destruction of violent impetus (i.e. projectiles). Fabri claims that it is destroyed "according to an exigence of something", lest the impetus "exist in vain" (Chapter 13). There are two ways which Fabri describes that may exact (*exigit*) this destruction: an impediment, which halts or impedes a projectile (e.g. a wall, or friction), or another impetus, in a different direction – which triggers the "impetus destruction" mechanism so extensively discussed in Part III of this book. There are two problems with this scheme. First, the causality surrounding impetus is incoherent: on the one hand, impetus, being an *ens*, is produced (*producitur*), while motion (not a pure *ens*) is exacted (*exigitur*) by impetus; on the other hand, the destruction of impetus – which should be expected to be *produced* (for its creation is produced) – turns out to be *exacted*. In short, Fabri is inconsistent in claiming that impetus is created by producing and yet destroyed by exacting. But the more serious problem is the one mentioned above: this "*frustra* logic" in effect empties the concept of impetus of any predictive physical significance. Given a body with certain impetus in a certain instant, we have no idea what it will do next, for we still do not know whether this impetus is *frustra* or not.

The physical role or status of impetus in Fabri's theory of free fall is also unclear. We have emphasized that in order to arrive at a purely kinematic analysis, which ultimately converges (assuming very small instants) to Galileo's, Fabri had to neutralize impetus as a factor having any influence on the rate of fall, at least in vacuum (where every object falls exactly the same, regardless of its properties). Fabri was no doubt well aware of a similar example of a discrete analysis of free fall that converged to a continuous one, in which impetus was totally absent: the theory of Isaac Beeckman, whose abandonment of impetus was praised by Koyré as signifying the "emancipation" of conservation of motion from the idea of impetus.[10] As is the case with CRM, impetus seems as merely a means implemented by Fabri to account for (and justify) insights he gained elsewhere, rather than a useful concept which helped him to develop (or enhance) such insights. Interestingly, Fabri himself seems to be perfectly aware of the possibility that the concept of impetus might be superfluous (at least in the context of free fall), for in theorem 12 of *De motu naturali* (book 2 of his *Tractatus physicus de motu locali*) he defends himself against an alternative explanation for free fall (involving the body's *gravitas* and the notion of "previous motion"[11]) by claiming (somewhat unexpectedly) that if such an alternative were true, "the impetus would be required in vain".[12]

Fabri succeeded then in assimilating important novelties concerning the theory of motion, and thereby managed to introduce some New Science essentials into the lion's den of the Jesuit establishment, the Jesuit College, through the back door.[13] However, this success came at a price, for this assimilation resulted in a problematic concept of impetus: Fabri cleverly utilized its potential for assimilating new ideas, but failed in his attempt to establish a better science of physics around it. While his theory is a sophisticated synthesis between the old ideal of *scientia* (causally explaining "sensible phenomena") and new physical essentials, as a complete and predictive physical theory, which can explain future observations and raise useful and meaningful problems (and thus become "a route to Normal Science", in Kuhn's terms), it was perhaps doomed to fail and be forgotten, exactly like its inventor. The concept of impetus became officially obsolete on 5 July 1687, with the publication of Newton's *Principia*; Fabri – one of its last proponents, and probably the last person to claim that "the whole of physics" depends on impetus – died less than a year afterwards.

Fabri's way of employing impetus brings us to the issue of his methodology, which also relies on his peculiar notion of "hypothesis" – a starting point in his deductive physical structure, aimed at reducing "sensible phenomena" to their causes. In keeping with the old *scientia* model, Fabri feels obliged to base physics on certain, or self evident building blocks, thus making sure that valid theorems are subsequently deduced. From this point of view, Fabri's methodology is very common to mid seventeenth century physics, characterizing also (at least to some extent) Galileo's experimental philosophy, which retained the traditional Aristotelian meaning of experience: Galileo, as well as Fabri, tried to ground physics on "statements of

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[10] Koyré 1978, p. 119, n. 80. See also Section 9.2, Note 29 above.

[11] On the view of *motus praevius*, adopted by the *Collegio Romano* Jesuit professor Muzio Vitelleschi (following Jacopo Zabarella), see Wallace 1978, pp. 408–409.

[12] "...praeterea si hoc esset, frustra requireretur impetus" (Fabri 1646b, lib. 2, th. 12, p. 82).

[13] It is probable that this success was the reason for removing him from his post as a teacher; see "Honoré Fabri: A Short Biography" above.

how things happen in nature”, rather than the on “how something *had happened* on a particular occasion” – that is, both of them traditionally abided by the Aristotelian directive to rely on common experience, rather than discrete events, as evidence for universal knowledge claims (Dear 1995, p. 125). Furthermore, Fabri accepted lock, stock and barrel all the experimental results reported by Galileo, and shared with Galileo (and with classical mechanics) the important recognition that the “true” behavior of physical bodies is exemplified under the ideal circumstances of vacuum. Fabri’s total acceptance of this important principle is clearly expressed in his remark that the mathematical proportions describing free fall “would be preserved very accurately” if “the heavy body were to descend in a vacuum” (See Chapter 8, note 17). However, nowhere does Fabri reveal the ingenuity by which Galileo showed that bodies indeed exemplify their “true” behavior in vacuum, and that under these ideal conditions there is to be found not only their most simple, but also their most general behavior – for example, a constant rate of fall.[14]

Another aspect of Fabri’s methodology which diverges from Galileo’s physical thinking, and might seem alien (or awkward) to us, is his (Aristotelian) insistence that we can only ascribe “physical” certainty to physics, which does not amount to the certainty that can be obtained in mathematics or metaphysics. Accordingly, as David Lukens observed, in Fabri’s system “the certainty in physics is not as great as the certainty in mathematics, because physical hypotheses are based on experiment; and the goal is not mathematical rules but a certain kind of causal analysis” (Lukens 1979, p. 184). Dear also emphasized that Fabri’s “essential problem with Galileo’s odd-number rule was that it could not be based on experience, or ‘experiences’, because sensory data could never provide sufficient precision to guarantee it” (Dear 1995, p. 141). Fabri expresses then, in accordance with his Aristotelian background, less firm belief in thoroughly “mathematized” physics than is to be found in Galileo’s (and our) view.

Fabri’s position will be better illustrated if we briefly reexamine his criticism both against Aristotle’s methodology and Galileo’s. Fabri blames the scholastic tradition for neglecting mathematics in general,[15] and accuses Aristotle in particular of failing to investigate natural acceleration, beyond offering a basic (i.e. qualitative) explanation why bodies fall. Fabri also specifically discredits Aristotle’s attempt to regard air resistance as responsible for natural acceleration. Galileo, for his part, included the latter explanation among the “fantasies” whose examination would hardly be useful (Section 7.2), and proceeded to a ground-breaking mathematical analysis, which could not but arouse Fabri’s admiration. Fabri indeed applauded Galileo for his mathematical analysis, but emphasized that such an analysis was simply not enough to be considered as “real” physics, since physics cannot give up, not even *ad hoc* and temporarily, the search for causes. Fabri thus rejected Galileo’s

[14] I mean of course Galileo’s experiments with bodies of various specific weights that fall in different media, from which he concluded that the inequality of speed decreases with the medium’s resistance, as well as his pendulum experiments, which served to “simulate” objects falling over long distances (Galilei 1989, pp. 75–76, 87–88). See also Van Dyck 2005, pp. 869–871.

[15] See Section 4.2 (Fabri’s letter to Mersenne).

methodological "manifesto", expressed in his introductory remarks to the 3rd day of *Two New Sciences*. In these remarks, Galileo had proudly announced to have discovered new *symptomata* of motion – the odd-numbers and the parabolic trajectory of projectiles – by which "there will be opened a gateway and a road to a large and excellent science of which these labors of ours shall be the elements, [a science] into which minds more piercing than mine shall penetrate to recesses still deeper" (Galilei 1989, p. 147). It was exactly Galileo's claim to have thus inaugurated a "new science" which Fabri found unconvincing. Galileo's contention that these (mathematical) "symptoms and properties"[16] by themselves constitute a basis for a new science must have been deemed by Fabri presumptuous; even though his own "manifesto", declaring impetus as the ultimate cause on which "not only motion itself but also the whole of physics depends" might sound in retrospect even more pretentious.

Another important issue concerning Fabri's concept of impetus is its impact on the two major Aristotelian dichotomies regarding motion: the dichotomy between natural and violent motion, and that between celestial and sublunary motion. As Jürgen Sarnowski has explained, these dichotomies were "called into question" by the medieval and early modern (many) concepts of impetus (Sarnowsky 2006, pp. 144–145). Fabri's mechanical scheme in general, and his notion of impetus in particular, served to further blur the difference between natural and violent motion, and also contained (as I shall soon explain) a substantial potential for achieving the same goal in the second dichotomy – though Fabri (perhaps intentionally) did not exploit this potential.

Part I has shown that the table of contents of Fabri's *Tractatus physicus de motu locali* exemplifies not the traditional difference between natural and violent motion, but rather the dichotomy between straight and circular (or curved) motion. This modern dichotomy is in fact deeply ingrained in Fabri's philosophy of motion, where the inherent linearity of impetus is emphasized and circular motion is regarded as resulting from an "impeded straight line". The fact that any impetus – whether natural or violent – is inherently rectilinear, and necessarily causes (when unimpeded) rectilinear motion, certainly serves to blur Aristotle's key distinction. It must be stressed that this linearity of impetus is totally alien to the medieval concept of impetus, and was first raised by Benedetti, in the late sixteenth century. It is also worth remembering that this property of impetus – which directly leads to CRM – is also a manifestation of the influence of Fabri's advanced philosophy of mathematics on his mechanical conception (especially in the context of introducing motion as a means for drawing curves).[17]

But the unity of Fabri's impetus – whether natural or violent – is even more far-reaching than the important common aspect of linearity. Part I has discussed

[16]This is Salusbury's translation of the term *symptomata*, which I find more appropriate than Drake's choice ("essentials"). Crew and De Salvio prefer simply "properties".

[17]See Section 15.2 above. I have emphasized there that additional research is required to further clarify this important connection.

extensively the crucial causal connection which Fabri established between impetus and motion, also noting the other side of the coin, the purposefulness of impetus. In Fabri's own terms, stating that impetus is a formal cause of motion is perfectly equivalent to arguing that motion is a "secondary formal effect" – i.e. the goal – of impetus. Thus Fabri expresses not only a strong link between any possible kind of impetus, with the consequent unprecedented unity of this concept, but also an important break in regard to scholastic (not to mention Aristotle's) natural philosophy. Scholastic natural philosophy, following Aristotle, intimately related teleology with natural processes, while systematically divorcing internal purposefulness from violent ones. Fabri, who may have been influenced by Thomas in his adoption of the formal causality of *natural* motion (along with the reciprocal purposefulness of its cause), was nothing less than revolutionary in ascribing formal causality to *violent* motion as well. Fabri's impressive declaration, that an unhindered impetus "would without doubt rejoice in its goal", i.e. in motion, not only constitutes a break from the scholastic (and Aristotle's) denial of (internal) teleology in violent processes, but also exemplifies Fabri's shift of emphasis from the category of substance to that of quality (Section 4.3). Although the two major fourteenth century theorists of impetus, Marchia and Buridan, did notice a "natural" aspect within violent motion, both of them emphasized its "violence" regarding the moving object; neither can be portrayed as sharing Fabri's "shift of emphasis" or approaching his well defined concepts of formal causality and inherent purposefulness which determine the mutual relation between impetus and (any kind of) motion. Finally, it is easy to connect Fabri's notion of CRM to this "intentionality" of the quality of impetus and its unprecedented prominence: while Fabri himself claims that substance *per se* tends to remain at rest (as long as it is connected to its *bonum*), nevertheless impetus – having a determined desire (or mind) of its own – is perfectly capable of enforcing a reluctant substance (in the absence of impediments) into perpetual motion.

The dichotomy between celestial and earthly motion is of course (in light of the historical circumstances) a more delicate issue. Fabri seems to have all the possible requirements which should have made it easy for him to further blur this ancient key distinction, beyond merely claiming (like Buridan) that impetus is (also) responsible for the motion of heavenly bodies.[18] Unlike Buridan and his medieval successors, not only does Fabri emphasize the linearity of impetus (connected, as already mentioned, also to his philosophy of mathematics) and adopt CRM, but he also dismisses the old celestial element of ether and claims that all the heavenly bodies are made of earthly elements;[19] furthermore, Fabri does not hesitate to conjecture that the

[18]Fabri 1648, lib. 5, p. 163 (just before def. 1).

[19]For example, the sun consists mainly of fire (Fabri 1669–1671, tr. 8, lib. 1, props. 5–6, pp. 222–236), while the (remaining) planets are – speculates Fabri – composed of metals (Fabri 1669–1671, tr. 8, lib. 1, props. 100–103, pp. 275–279). He finds it especially hard to ascertain the composition of stars, but emphasizes that they are in any case made of no "pure element" (Fabri 1669–1671, tr. 8, lib. 2, prop. 4, p. 285). The rejection of Aristotle's quintessence was common among Jesuits: "the theses of Brahe and Galileo on the 'fluidity' of the heavens and against the

trajectories of Jupiter's moons around this planet are parabolas, the curve Galileo used to describe earthly projectiles.[20] Fabri then could easily have followed Kepler, and eliminated (or almost eliminated) the celestial/sublunary dichotomy: for why should celestial impetus – in a sky composed not of ether (which in Aristotle's system indeed enforces on itself eternal circular motion), behave differently than earthly impetus, which exacts straight motion? Fabri, according to his general conception of circular motion as an "impeded straight line", asserts (Section 15.2) that a stone in a sling tends to move along a straight line tangential to its trajectory, and would actually do so if the "impeding" rope were cut; why does he not claim that by the same token, a planet tends by itself to continue along a straight line tangential to its trajectory, and would do so unless there was a factor "impeding" this inherent linearity (to be subsequently identified by Newton as universal gravitation)? Fabri chose to claim otherwise, and preferred to reject heavenly rectilinear tendencies and adhere to natural circular non-terrestrial motions.[21] Judging by the artificial (and not very convincing) character of the difference Fabri supposes between the working of impetus on earth and in the sky,[22] it seems a probable conjecture that Fabri – as a Jesuit, *ipso facto* prevented from embracing Copernicanism – was prudent enough not to apply the consequences of his overall concept of impetus to the dangerous field of celestial physics, whereas there was no reason for such prudence concerning terrestrial physics, where Fabri felt absolutely "safe". Further research of Fabri's celestial physics, especially the manner in which impetus produces the heavenly trajectories, is required in order to provide a more decisive answer to this intriguing question.

In order to further comprehend Fabri's concept of impetus, it seems to me crucial to differentiate between two aspects of his important adopted principle of CRM: the aspect of discovery and the aspect of justification.[23] There can be no doubt that Fabri discovered this idea in the writings of the senior representative of the New Science: starting with its beginnings among the works of Benedetti and Galileo, through Beeckman and Gassendi, and finally in the full blown expression of this principle by Descartes and Galileo's disciples. However, Fabri's justification of the principle of CRM – namely, an unfailing impetus – is of course scholastic, though the special priority he places on the quality of impetus is unprecedentedly alien to Aristotle's "substance centered" way of thinking. How could Fabri come up with his concept of impetus as a "super quality", as an entity with a desire of its own (to

Aristotelian dualism of heavenly and earthly matter had few opponents after 1630" (Baldini 1999, p. 266).

[20] See "Introduction", Note 21 above.

[21] Interestingly, in his *Physica* Fabri attributes to the sun a trajectory which arises from a constant circular motion combined with a linear one – in effect an ellipse ("Hinc iam habetur motus solis mixtus ex circulari aequabili & recto ab apogaeo ad perigaeum, & vicissim, accelerato & retardato"; Fabri 1669–1671, tr. 8, lib. 3, p. 334).

[22] Contrary to Aristotle's coherent scheme of celestial ether which causes circular motions, in Fabri's system it is not clear why impetus exacts inherent linear motion only as high as the moon.

[23] Despite Kuhn's skepticism concerning the validity of this distinction (Kuhn 1970, p. 9).

confer motion) which can easily overpower any substance and drag it along (in ideal circumstances) to infinity?

This issue brings us directly to theology. As Section 18.1 in Part IV has shown, Fabri declares that the "primary qualities" of bread and wine – namely, their primary heat (i.e. the direct heat of fire particles) and innate impetus – perform all the functions of their substances, once the priest's blessing has been uttered and Transubstantiation has been effected. Here Fabri has an example of qualities which gain – in the course of this miracle – a status which competes with the old Aristotelian distinguished category of substance. Fabri subsequently insists that unlike primary heat, innate impetus (which he identifies with gravity) is necessary for explaining the miracle of the Eucharist, because absolute levity does not exist – a fact that renders innate impetus (i.e. absolute gravity) necessarily present in any portion whatsoever of matter. Fabri's latter observation not only proves the strength and persistence of the Archimedean abolition of levity in his thought (which Fabri sees fit to incorporate into such a theological explanation), but also emphasizes the affinity between the priority of (innate) impetus in the field of theology and the key role of (violent) impetus within the theory of motion: both are promoted to a substance-like status, either by taking the substance's place or by coercing it to behave against its own nature. Fabri himself never claims that it was the key role of innate impetus within the miracle of the Eucharist which encouraged him to use the energetic and "ambitious" quality of violent impetus to justify (or guarantee) CRM. However, it seems to me plausible to speculate that the primacy of qualities (at least those denoted as "absolute", or in Fabri's terms: non-modal)[24] was considered by Fabri as a useful and relevant means to justify such a revolutionary and anti-Aristotelian concept like CRM among members of his order, so committed to this important ritual, a commitment which so much irritated their enemies.[25]

The issue of the Eucharist, and its possible influence on Fabri's philosophy of nature, reveals an even closer link between Fabri's philosophy of motion and his philosophy of matter. Weisheipl estimates that "were it not for the Eucharist, Ockham would have denied absolute reality to every accident", and so would have admitted the absolute reality of substance alone, dismissing qualities (Section 19.2). We have seen, in Part IV, that the theory of the Eucharist directly influenced Fabri's philosophy as well. Fabri himself mentions this sacrament as the reason for rejecting the identification of body (*corpus*) with "actual impenetrability", and in order to account for the Eucharist he defines body as something which only exacts (*exigit*) impenetrability.[26] Fabri's use of the concept of impenetrability, part and parcel of the atomistic

[24]The teaching of which in any case being "occasioned by the doctrine of the Real Presence of the Body and Blood of Christ in the Eucharist"; see Chapter 17 above; Baldini also emphasizes that "the *qualitas* was defended [by Jesuit scholars] because of its role in the explanation of the Eucharistic miracle" (Baldini 1999, p. 272, n. 91).

[25]Antoine Arnauld, in his popular *Frequent Communion* (1643), famously attacked the Jesuits by discouraging "the reception of the Holy Eucharist, even to the point of recommending abstention as a form of penance"; Bangert 1986, p. 205.

[26]Thereby allowing God to suspend this "exigence", following the priest's blessing.

discourse, is of course important, as well as the employment of the verb *exigere* – which immediately brings to mind Fabri's concept of impetus that exacts motion. Indeed, the close affinity between Fabri's theories of matter and motion is manifest in his claim that anything that can move requires association with impenetrability[27]: if we add this to Fabri's definition of "body", we may argue that according to Fabri a "body" is nothing but an object which (thanks to its association with impenetrability) can theoretically move. All these, along with the reduction to six concepts Fabri recommends in his letter to Leibniz (the four elements, and the two non-modal qualities impetus and heat; see Section 4.3) – should be seen as the constituents of Fabri's unique synthesis between scholastic philosophy of matter and early modern theory. As we have seen in Section 19.4, Fabri adamantly opposes substantial forms (except man's, i.e. the soul), but retains qualities – i.e. accidental forms – while closely connecting both qualities with motion (by claiming that the two non-modal qualities – impetus and heat – cause, respectively, local motion and expansion), as well as matter with motion (using the atomistic notion of impenetrability).

Finally, it is important to discuss the status of physics within Fabri's overall view of philosophy. The traditional scheme – established by Aristotle and supported by Thomas Aquinas – endorsed the following division of the "speculative sciences": metaphysics (the investigation of "being as being"), physics (i.e. natural philosophy) and mathematics. Fabri endorsed a different division. According to him, "the speculative sciences are to be distinguished by the nature of their different objects, for every object is either corporeal or incorporeal, or abstracted from both, i.e. predicated of some universal which is in corporeal or incorporeal being (*quippe omne obiectum vel est corporeum, vel incorporeum, vel ab utroque abstractum, id est praedicatum aliquod universale, quod inest enti corporeo & incorporeo*). If the object is corporeal the science is called physics... if it is incorporeal the science is called natural theology... if it is abstracted from both, the science is called metaphysics".[28]

By defining metaphysics as a separate discipline, to be differentiated from theological matters dealt with in natural theology, Fabri expressed the Jesuit tendency to regard metaphysics as a necessary preliminary not to theology alone, but also to natural philosophy (which Baldini defines as "*physica*"). As Baldini explains, metaphysics "set the parameters of acceptability for the 'physical' doctrines, and 'demonstrated' principles already in use in the teaching of *physica* without a formal justification" (Baldini 1999, p. 260). This is certainly true concerning Fabri, who uses "metaphysical axioms" within his deductive scheme of physics outlined in his *Tractatus physicus de motu locali*, and generally regards metaphysics as a discipline investigating "universal concepts" (*rationes universales*; Chapter 2 above). However, Baldini's depiction of a "formal subordination to metaphysics" among the Jesuits (ibid., p. 261) seems dubious (at least in Fabri's case), as is his insistence on the strength of the Jesuit "link between *physica* on the one hand and metaphysics and

[27] Any entity can move, explains Fabri, "if only joined to impenetrability" (Chapter 17 above).

[28] Lukens 1979, pp. 112–113 (his translation); Fabri 1646a, lib. 1, cap. 1, art. 2, p. 3.

theology on the other" which rendered change "more difficult and gradual" (ibid., p. 274). Fabri's metaphysical analysis of "place" and "time" served not to render change more "difficult", but rather to introduce into the field of physics intrinsic non-Aristotelian notions of space and time, thus releasing them from external chains, i.e. dependence on a material medium (in the case of place) or on motion (in the case of time). Fabri was of course not the first Jesuit to adopt (through this "generalizing", rather than limiting, device of metaphysics) such abstract concepts (as Section 14.1 has shown), though he was certainly the first among the members of his order to accept the modern ultimate result of motion without resistance – CRM.

Furthermore, despite using "metaphysical axioms", and his use of metaphysics not only to justify non-Aristotelian ideas, but also to implicitly account for the convergence of his law of fall to Galileo's,[29] Fabri (*pace* Baldini) seems keen on preserving the autonomy of physics as a discipline pursuing an experimental enterprise, aimed at a reduction of sensible effects to causes. Not only does he not find in the *Tractatus* any use for Aristotle's famous metaphysical definition of motion (*actus entis in potentia, prout in potentia*), but he also sees fit to explicitly dissuade his reader from consulting his own *Metaphysica demonstrativa* concerning this subject, and the complicated issue of modes as well.[30]

Last but not least, Fabri seems anxious to purge physics of an annoying issue, which had plagued it for centuries: the unsolvable problem of the Real Presence, the manner in which Christ resides in the host after the consecration. In a cunning move, in which he identifies Christ's body with the bread's internal quantity, consequently branding internal quantity as a metaphysical (rather than physical) property of body, Fabri manages to transfer this problem from the realm of sensible effects (physics) to the deeper discipline of universal concepts (metaphysics). This allows Fabri to ultimately claim that *physice*, nothing really happens during Transubstantiation. Furthermore, by solving the second problem of the Eucharist – i.e. the Accidents problem – using the concept of (innate) impetus, Fabri could display the power of his impetus-based physics. This strategy may have enabled Fabri to pursue his vigorous activity within the *Accademia del Cimento* while neither relinquishing his faith, nor feeling awkward (or inept) among non-Jesuit *Accademia* members.

It may be worth emphasizing, in this theological context, the different employment of impetus (or its close forerunner, *vis derelicta*) within the explanation of the Eucharist, by Marchia in the fourteenth century and by Fabri in the seventeenth century. While Marchia used *vis derelicta* in order to explain the mind-boggling phenomenon of Real Presence (i.e. how Christ continues to reside in the host), Fabri used impetus rather to explain the other side of the coin – the perfectly "sensible" Accidents problem (i.e. why we continue to see bread and wine, even after

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[29] Fabri himself refers the reader of his *Tractatus physicus de motu locali* to the *Metaphysica demonstrativa* concerning the notion of instant, to be ultimately defined as "actually discrete and potentially continuous" (see Section 9.1); it is explained in Section 11.1 and the appendix why this concept is pertinent to Fabri's convergence proof.

[30] See Notes 2, 3 in Chapter 3 above.

Transubstantiation). Indeed, Fabri's overall concept of physics – though still far from being describable as "classical" – should be seen as a fascinating (if not altogether successful) attempt of integrating into a rich and powerful tradition not only some important novelties of the emerging New Science, but also at least part of the fresh pre-modern frame of mind which would soon bloom and evolve into the *Zeitgeist* of the Age of Enlightenment.

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Appendix: The Proof of Convergence to Galileo's Law of Fall

One of the most basic requirements of any physical law is scalar invariance, namely – in the words of Carla Rita Palmerino – its being "valid irrespective of the units chosen to measure space and time" (Palmerino 2003, p. 201). This important property of physical laws was recognized by Fabri's cotemporaries, especially supporters of Galileo's "odd numbers rule" for falling bodies. The French mathematician Jacques Alexandre Le Tenneur (1610–1660), who was asked by Mersenne to defend Galileo's law against the "attacks" of the "most acute" Fabri (Palmerino 1999, p. 319), praised its scalar invariance, which guarantees that

> the multiplication of times according to any proportion whatsoever always confirms to the uniform proportion among the spaces, and it does not happen that you get a larger or a smaller space if the equal times get longer or shorter [. . .]. Nor will there be a larger ratio between four spaces and two spaces, than between two spaces and one space; nor will there occur a larger or smaller space. [. . .]. But all is found to cohere and agree marvelously.[1]

Indeed, Galileo's law of fall – the series 1, 3, 5, 7, 9, 11, 13, 15 etc. for consecutive distances – is scalar invariant: any time unit we choose will essentially amount to the same original series. If we choose one second as our basic time unit, the series will be simply 1s, 3s, 5s, 7s, 9s, 11s, 13s, 15s. . .; if we choose two seconds, we obtain (1+3)s, (5+7)s, (9+11)s, (13+15)s, (17+19)s, (21+23)s, (25+27)s, (29+31)s. . ., i.e. the series 4s, 12s, 20s, 28s, 36s, 44s, 52s, 60s. . . which retains the original proportion 1, 3, 5, 7. . .; if we choose eight seconds, we obtain 16s, 48s, 80s, 112s. . ., which yields again (after division by 16) Galileo's original series.

Fabri's law – as Le Tenneur recognized – is not scalar invariant. As the latter noted in his *De motu naturaliter accelerato tractatus physico-mathematicus* (1649), "it must needs be the case that the first space is to the second space like the two first spaces to the two subsequent ones, as has been shown against Fabri, because we obviously need a principle of uniformity in natural events as these need to proceed in an uninterrupted course."[2] If we check what happens to Fabri's series (the simple natural numbers sequence 1, 2, 3, 4, 5. . .) when we choose increasingly greater units

[1] Palmerino 1999, p. 320 (quoted from Le Tenneur's letter to Mersenne, dated 13.4.1647; Palmerino's translation).

[2] Palmerino 1999, p. 322; Palmerino's translation.

of time, it turns out that Le Tenneur was indeed correct in claiming that "a principle of uniformity" is absent in the case of Fabri, for the series constantly changes; but it also appears that Fabri's series changes into a sequence which we already know:

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20... ($t = 1$)
3, 7, 11, 15, 19, 23, 27, 31, 35, 39... ($t = 2$)
10, 26, 42, 58, 74, 90, 106, 122, 138, 154... ($t = 4$)
36, 100, 164, 228, 292, 356, 420, 484, 548... ($t = 8$)
136, 392, 648, 904, 1160, 1416, 1672, 1928... ($t = 16$)
528, 1552, 2576, 3600, 4624, 5648, 6672... ($t = 32$)

The last sequence yields, after a "normalization" (i.e. dividing by 528) the series 1, 2.94, 4.88, 6.82, 8.76..., which comes quite close to Galileo's series 1, 3, 5, 7, 9... It is easy to see that if we choose bigger units of time, the resulting series will come even closer to 1, 3, 5, 7, 9.

The same effect of "convergence" will be obtained if we consider a given "sensible" phenomenon – i.e. a phenomenon perceived by the senses – and use increasingly smaller units of time to measure it: obviously, the smaller the unit of time (i.e. "instant") we choose, the closer the perceived phenomenon (a measured distance) will come close to Galileo's prediction. This is exactly what Fabri proves, in his "Dissertation on Naturally Accelerated Motion", following theorem 61 of *De motu naturali deorsum* (the second book of the *Tractatus physicus de motu locali*).

Let us imagine (Fig. 1) a body falling during a "sensible" period of time – say, two seconds (AE and EF, uppermost line). According to Galileo's series – i.e. according to our observation *de facto* – if the falling body passed a distance GH during AE, it will pass HL = 3GH during the next second EF; during the two seconds combined it will have passed GH + HL = GL = 4GH. Being scalar invariant, in Galileo's analysis it does not matter which unit of time is used to measure this phenomenon. Such is not the case according to Fabri's law. If we consider

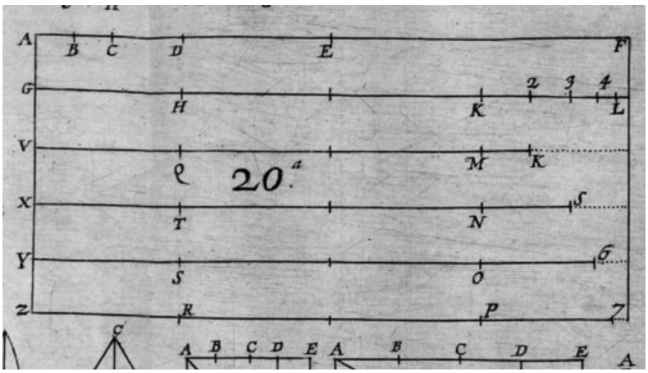

Fig. 1 Fabri's proof of convergence (Fabri 1646, tabula I)

AE = EF as our unit of measure ("instant"), the difference between the real result (Galileo's) and the result predicted by Fabri's theory will be substantial: if within AE the body passes GH (second line from the top), then during EF it will pass HK = 2GH (according to 1, 2, 3, 4....), and the difference between the overall sums (predicted by Galileo and Fabri) will be: KL = GL – GK = 4GH – 3GH = GH = **GL/4**.

If we consider AD = 0.5AE (uppermost line in the figure) as an "instant" – our basic unit of time – then the distance GH will be passed by two consecutive instants (AC + CD), i.e. GH will constitute 1 + 2 = 3 basic units of distance, while during the next two instants the body will pass 3 + 4 = 7 basic units of distance (according to the new series, 3, 7, 11, 15, 19....). if the body passes VQ = GH = 3 units of distance within the first two instants, then it will pass QK = 7/3 · VQ = 7 units of distance during the following two instants (third line from the top). The difference between Galileo's (i.e. the correct) result and Fabri's will be smaller:

$$\begin{aligned} GL - VK &= GL - (VQ + 7/3 \cdot VQ) = 4GH - 10/3 \cdot GH = 2/3 \cdot GH \\ &= 2/3(GL/4) = \mathbf{GL/6}. \end{aligned}$$

If we consider AC = 0.25AE (uppermost line) as an instant, then in the first four instants (constituting AE) the body passes 1 + 2 + 3 + 4 = 10 units of distance, and in the following 4 instants (constituting EF) 5 + 6 + 7 + 8 = 26 units of distance (the new series will be 10, 26, 42, 58...). If the body passes XT = GH = 10 units of distance within the first four instants, then it will pass TS = 26/10 XT = 26 units of distance during the following four instants (fourth line from the top). The new difference between Galileo's and Fabri's results will be now even smaller:

$$GL - XS = GL - (XT + 26/10 \cdot XT) = GL(1 - 1/4 - 26/40) = \mathbf{GL/10}.$$

Now Fabri shows by induction that the difference between Galileo's and his results is GL/(n+2) – where n is the number of instants which make the total time, i.e. AF – and therefore "the amount by which the distance, calculated by his hypothesis, falls short of the reported measured distance is always 1/(n+2) of the measured distance" (Lukens 1979, p. 188). As Fabri explains, the process of further dividing AE and EF can go on forever, and each division will bring us closer to Galileo's law, since the greater is n, the smaller is that difference. In Fabri's words, "the two parts of time AE, EF can be divided into nearly infinite instants. Hence if there are only 1,000,000 instants, the space acquired will be smaller than the space taken as true by 1/1,000,002, and who can detect that? ...therefore since both our hypothesis and Galileo's can fit the experiment, therefore neither one can be overcome from this experiment".[3] I have already pointed out (in Section 11.1 above) that Fabri's characterization of time as composed of "physical" instants, which are "potentially divisible" (extrinsically), despite being "actually indivisible", in

[3]Lukens 1979, p. 188; Fabri 1646, lib. 2, th. 61, p. 102 (Lukens's translation).

effect ensures convergence to Galileo's law. For the (extrinsic potentially) divisibility of such a "physical" point guarantees that given any instant – no matter how small – a smaller one will always be found (see Section 9.1 above), which means that the process of dividing AE and EF can be continued as long as we like, and necessarily arrive at the point in which it would be utterly impossible to discern any difference between Fabri's series and Galileo's.

The convergence of Fabri's (discrete) analysis to Galileo's (continuous) approach – under the assumption of increasingly smaller instants – is of course a rather trivial mathematical fact, which can be easily illustrated geometrically. Fabri indeed supplies a diagram (Fig. 2) – in which the horizontal "axis" FN represents time, and the vertical "axis" FA represents velocity – and explains that the sum of quadrangles which constitutes the total distance in a discrete analysis[4] becomes closer to the triangle AFN (i.e. the total distance in Galileo's continuous analysis) when the whole time FN is divided to more and more instants.[5] Indeed, within the triangle AFN, consecutive areas over consecutive equal periods of time (e.g. GIPO,

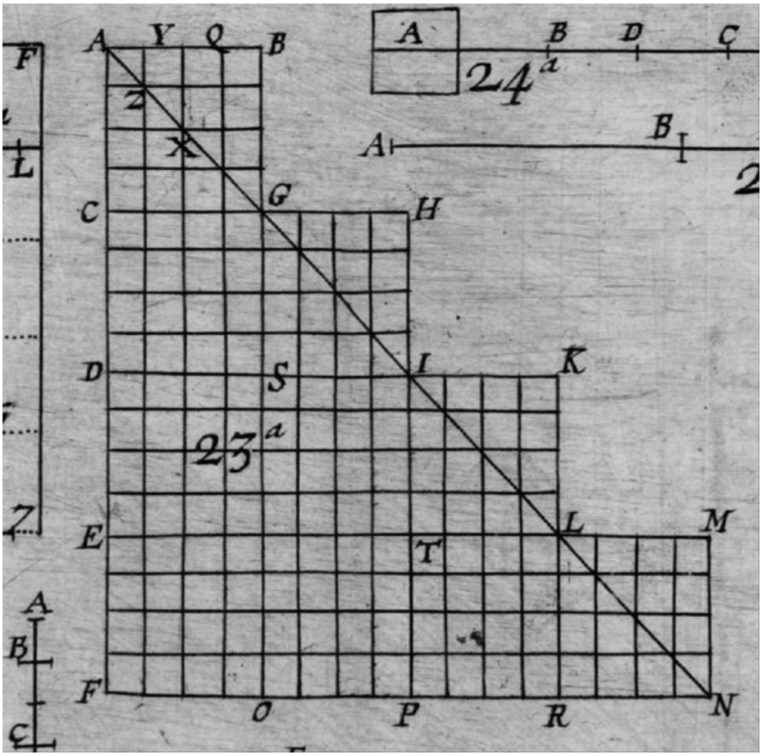

Fig. 2 Fabri's "discrete" diagram (figure 23; Fabri 1646, tabula I)

[4]In figure App 2: the quadrangles LMNR, IKRP, GHPO and ABOF (assuming an "instant" RN=PR=OP etc.); these areas behave of course like the natural numbers series.

[5]Fabri 1646, lib. 2, th. 61, p. 106; Lukens 1979, p. 192.

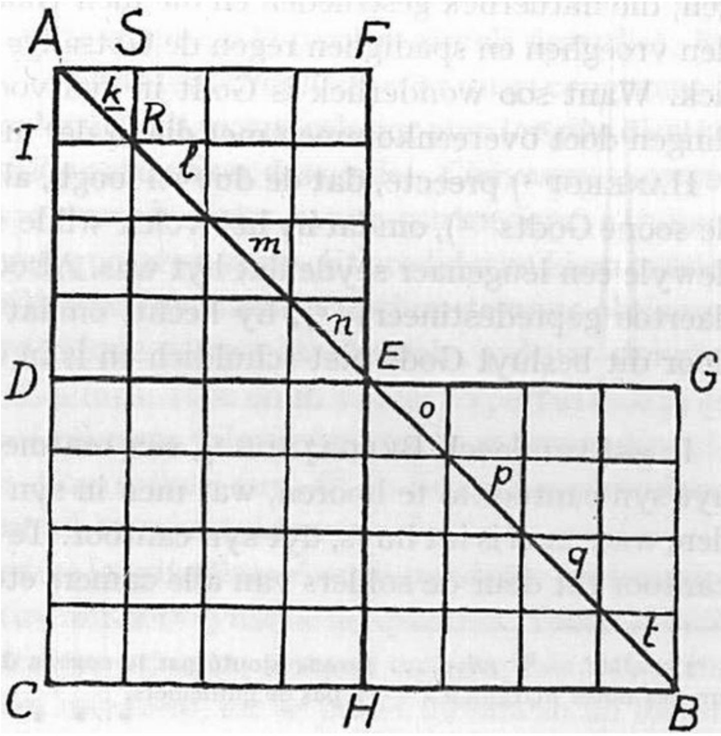

Fig. 3 Beeckman's "discrete" diagram (appears as fig. 60 in Beeckmann 1939, Vol. 1, p. 262)

ILRP and LNR in Fig. 2) behave like the series 1, 3, 5..., and clearly the more instants we employ in a discrete approach the closer we arrive to the continuous outlook. This fact was already noticed by Isaac Beeckman in 1618, who also supplied a similar diagram (Fig. 3) to illustrate the same point, namely the convergence of a discrete analysis to a continuous one.[6] As mentioned before, there can be little doubt that Fabri was well aware of such earlier accounts, possibly including Beeckman's.

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[6]See Damerow et al. 2004, pp. 31, 39 and Dijksterhuis 1961, pp. 330–331.

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