Self-Translation of Mathematical Texts in Seventeenth-Century France:
The Cases of Pascal, Mersenne and Hérigone

Submitted by Seán Morris to the University of Exeter
as a thesis for the degree of
Doctor of Philosophy in Modern Languages
in April 2021

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University has been acknowledged.

Signature: 

Abstract

This study investigates self-translation – the process of producing a second version of a text in another language – as it relates to three pairs of mathematical works created in Latin and French in mid-seventeenth-century France: Pierre Hérigone's *Cursus mathematicus* and *Cours mathématique*, Marin Mersenne's *Harmonicorum libri* and *Harmonie universelle*, and Blaise Pascal's treatises on the Arithmetic Triangle. The investigation uses case-study methodology and self-translation research as a framework to examine why and how the three scholars produced bilingual versions of their texts, and does so against the background of the most significant contemporary social and historical factors. As research into pre-twentieth-century non-literary self-translation, it examines material and practices that have largely fallen outside the most frequently investigated areas of self-translation research.

The study shows that the most common reasons for writing bilingual works in France during the period in question were related to the emergence of new and changing audiences. This was particularly attributable to the changing relationship between Latin and French: the early seventeenth century was a time of flux, where French was gradually taking over from Latin in French scholarly writing and was the language of the scientific *cabinets*, attended by an increasingly educated populace, while, at the same time, Latin was consolidating its position as the language of the pan-European Republic of Letters. Many French scholars who wished to maximise their audiences, both within France and across Europe, chose to write their works in Latin, slightly more opted for French, while others, including the case-study scholars, chose to compose their books in both languages. Other, more individual factors were involved in the case-study authors' decision to self-translate, including the desire to develop ideas, teach mathematics and compose a significant musical work for as large an audience as possible. The different types of text composed by the three mathematicians and their differing motivations led to a range of approaches to self-translation and a variety of outcomes. Some features of the bilingual works are common to all three case studies, including the use of French mathematical terminology derived from its Latin equivalents, a desire to accommodate different audiences for the texts in the two languages, and the use of rhetoric, including 'mathematical rhetoric', in both Latin and French.

Table of contents

Acknowledgements

This thesis has benefitted from advice and support from a number of quarters. My two research supervisors, Professors Michelle Bolduc and Chloe Paver, provided excellent advice and support throughout the three-and-a-half years of my research, reading the many drafts of my individual chapters and the final draft of the complete thesis, asking penetrating questions, pointing me in the right direction towards fruitful avenues of research, all with wisdom and patience.

My research also benefitted from three years of generous financial support in the form of an award from the Vice-Chancellor's Scholarship for Postgraduate Research, extended because of the pandemic towards the end of my research, for which I am very grateful.

My work was supported ably by a group of people who often do not receive the thanks they deserve: the staff of the university library. It is thanks to their unfailing patience and immense knowledge that I have been able to locate so many resources within the university and from around the country to enrich my research.

I could not have completed my research without the support of my family, Julie, Siobhán, Liam and Ciarán, who showed immense patience through the entire process. Particular thanks go to Julie for twice reading the final draft of the thesis and making thoughtful suggestions.

Table of figures

Definitions and editorial principles

Definitions of terms used throughout the thesis

Mathematics

Traditionally, mediaeval mathematics included the quadrivium of arithmetic, geometry, music, and astronomy (Katz 2014: 354). By the Early Modern period, there existed a distinction between ‘theoretical’, or ‘pure’, mathematics on the one hand, and ‘mixed’, or ‘applied’ mathematics on the other. Pure mathematics consisted of arithmetic, geometry, trigonometry and algebra, while mixed mathematics included mechanics, physics, optics and catoptrics, hydrostatics and hydrodynamics, architecture and perspective, the geometry of the sphere, astronomy, geography, navigation and cartography, fortification and other military arts, and other practical subjects (Davis and Hersh 1986: 9–10; Henry 2008: 5; Saiber 2017: 119). For the purposes of this thesis, ‘pure mathematics’ and ‘mixed mathematics’ are defined as above, while ‘mathematics’ on its own refers to the full set of pure and applied subjects.

Science

Early Modern scholars investigated ‘natural philosophy’, which is closely related to what we understand by the term ‘science’ today, but broader in scope (Principe 2011: 27). So, although the terms ‘science’ and ‘scientific’ are anachronistic with respect to the Early Modern period, in this thesis I use them in their modern sense to describe seventeenth-century natural philosophy.

Literary and non-literary writing

The opposition between literary and non-literary works, translations and self-translations is also anachronistic with respect to the Early Modern period. Glyn Norton points out that, historically, genre labels are unfixed, and subject to a process of continuous modification (1999b: 9): the contrast between ‘literary’ and ‘non-literary’ works would therefore have been meaningless at a time when such fields as ‘science, theology, classical scholarship, cosmogony, rhetoric, poetics, and philosophy’, amongst others, were linked together (Norton 1999b: 2). Ann Blair further notes that, until well into the seventeenth century, ‘the methods, goals, and individuals involved in [science and literature] overlapped in a number of ways' (1999: 449) and that literature and science were only just beginning to 'form distinct conceptual worlds' at this time (1999: 457). The terms 'literary' and 'non-literary', as used to contrast types of self-translation in this thesis, should therefore be understood in their modern senses: 'literary' writing refers principally to poetry, theatre and fictional prose, while 'non-literary' writing encompasses all other genres, generally non-fiction in nature, including scientific and mathematical texts (Bertrand 2015: 87).

Paratext

Paratext is a concept developed by Gérard Genette (1997a, 1997b). Kathryn Batchelor summarises his notion of paratext succinctly as 'any element which conveys comment on the text, or presents the text to readers, or influences how the text is received' (2018: 12). Genette separates paratext into two types. Paratext found in the same volume as the text frames the text and is known as the 'peritext' (Genette 1997b: 4–5; Macksey 1997: xviii). The peritext is made up of a range of elements, including the author's name or pseudonym, a title, subtitles, intertitles, prefaces, dedications, postfaces, notices, forewords, afterwords, notes (marginal, infrapaginal and terminal), epigraphs, epilogues, illustrations, blurbs, book covers and dust jackets (Genette 1997a: 3, 1997b: 3; Macksey 1997: xviii). The peritext may be 'allographic' (i.e. produced by a third party) or 'authographic' (i.e. produced by the author) (Genette 1997a: 3). Paratext that lies outside the text but determines its reception, such as authorial correspondence and diaries, is known as 'epitext' (Macksey 1997: xviii). When I refer to paratext in this thesis, I will mainly be discussing peritext.

European historical periods and movements

All historical periods are constructs used 'to give structure to historical narratives, as signposts [...] to organize the endless flow of history' (Lotz-Heumann 2019b: 2). That is precisely my purpose in defining them as below for my research: to enable me to define and name the period within which the case-study authors were working, i.e. the Early Modern period, and the periods that preceded it.

Classical Antiquity: refers to the period from approximately the fifth century BCE to the end of the fifth century CE (Boardman et al 1986: 830–60).

The **Middle Ages**: refers to the period between approximately 500 CE and 1500 CE (Rubin 2014: 1).

The **Early Modern period**: the period that lasted from approximately 1450–1500 CE to 1750–1800 CE (Lotz-Heumann 2019b: 1; Scott 2015b: 1). This period incorporated some of the Renaissance and all of the Scientific Revolution.

The **Renaissance**: there is consensus that this period lasted from approximately 1400 CE to 1600 CE (Brotton 2006: 9). Consequently, most scholars place the start of the Italian Renaissance in the late Middle Ages (Lotz-Heumann 2019b: 2). Jules Michelet (1798–1874), the nineteenth-century French historian, placed the French Renaissance in the sixteenth century, during the Early Modern period (Brotton 2006: 10). When I refer to the Renaissance in this thesis, it will be to the Renaissance as it relates to the country under discussion.

The **Scientific Revolution**: generally considered to be approximately the period from 1500 CE to 1700 CE (Principe 2011: 2).

The **Republic of Letters**: 'a European community of minds' that was first established in fourteenth-century Renaissance Italy, spreading across Europe by the sixteenth century (Fumaroli 2018: 5–7, 36). The seventeenth-century Republic of Letters could be characterised as 'a contemplative society [...], united by letters, [...] in the same intellectual adventure' (Fumaroli 2018: 14).[1]

Editorial principles

Translations

All translations in the text are my own, except if credited otherwise, and are presented in square brackets following the original text. Ellipses in translated text will be presented in ordinary parentheses.

Spelling and punctuation in quotations and titles

Of the three case-study authors, Pascal alone has had his works collected and edited since the seventeenth century. The only available versions

[1] A fuller account of the Republic of Letters can be found in section 2.3.2.

of the other case-study works are therefore original editions or early reissues of the original editions. For the sake of consistency, I have chosen to use seventeenth-century editions of all three works, including Pascal's treatises on the Arithmetic Triangle. This decision has consequences for spelling and punctuation in quotations from the case-study texts and the titles of the component parts of the works.

Spelling and punctuation in quotations from the case-study texts will reproduce the spelling and punctuation of the original works, including the use or, more frequently, absence of accents, but will omit typographical accents. Exceptions to the exact reproduction of spellings will include use of the letters 'i' and 'j', and 'u' and 'v', which was not settled in the Early Modern era, and use of the ampersand (&), which will be replaced by 'et' throughout. Italicised and capitalised text in quotations will be retained to present an accurate picture of the *mise-en-page* of the texts. The same conventions will be followed for other Early Modern works, except where original editions do not exist, as in the case of Pascal's *De l'esprit géométrique*, for example.

All scientific and mathematical works will be cited using the spelling in the *Dictionary of Scientific Biography* (Gillispie 1981). This will include the case-study works, as all have accepted versions of their titles in common usage. As Pascal's treatises have been regularly collected and edited since the eighteenth century, the separate treatises in his work all have standard titles, which I will use throughout the thesis and which can be found in appendix 6. The same is not true of the books in the *Harmonie universelle* and *Harmonicorum libri* or the sections of text and paratext in the six volumes of the *Cursus mathematicus* and *Cours mathématique*. Consequently, I will use the original spellings for the various sections of Mersenne's and Hérigone's works, as set out in appendices 4 and 5. All other pre-modern works will be cited in the thesis using the generally accepted modern titles, where these exist.

Names and dates of mathematicians

The names of mathematicians cited in this thesis are the versions used in the *Dictionary of Scientific Biography*. For most mathematicians, this is their name in their culture of origin. However, in some cases, the name by which a mathematician is generally known differs from his birth name. This is true, for example, of Christoph Clavius (1538–1612), whose original German surname is unknown (O'Connor and Robertson 2008). Dates of birth and death for mathematicians are also those found in the *Dictionary of Scientific Biography*, where these are known. The three cases-study authors and their dates are: Pierre Hérigone (died circa 1643), Marin Mersenne (1588–1648), and Blaise Pascal (1623–1662). Dates for all other scholars are taken from the online versions of the *Encyclopaedia Britannica* and other similar encyclopaedia.

Editions, titles and pagination of the case-study works

Complete information about the editions of the case-study works used in this thesis, their full titles, the titles of their component parts, and matters relating to pagination can be found in the appendices: appendix 4 for Hérigone's *Cursus mathematicus* and *Cours mathématique* [Mathematics Course] (mainly referred to in the thesis simply as the *Cursus*), appendix 5 for Mersenne's *Harmonie universelle* [Universal Harmony] and *Harmonicorum libri* [Books on Harmonics], and appendix 6 for Pascal's two collections of treatises on the Arithmetic Triangle, including the second, published collection, known under its modern title as the *Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière* [Treatise on the Arithmetic Triangle, with other Short Treatises on the Same Subject].

Introduction

The first half of the seventeenth century was a period of flux in a number of important areas of French intellectual life. This was the period – known commonly, but not universally, as the Scientific Revolution – when changes that had been developing for many years in approaches to science culminated, 'arguably' in John Henry's words, in the establishment of 'the conceptual, methodological and institutional foundations of modern science' (2008: 1), replacing Aristotelian natural philosophy, which had dominated scientific thinking since the late Middle Ages (Henry 2008: 3; Dear 2009: 8–9). One of the most important aspects of the Scientific Revolution was 'the increased use of mathematics to understand the workings of the natural world' (Henry 2008: 17), particularly in carefully designed experiments based on real-world phenomena in some, but not all, areas of natural philosophy (Cohen 2016: 158).[2] French mathematicians were key to mathematical progress during this period: as Uta Merzbach and Carl Boyer conclude, 'France was the undisputed mathematical center during the second third of the seventeenth century' (2010: 308). At the time science and mathematics were undergoing significant change in France, the same was also true of the language used in scientific research and publications. Blair has located the 1630s and 1640s as the period when European scholars, particularly in Italy and France, first began to seriously consider abandoning Latin alongside their rejection of Aristotelian science, 'pour recommencer la philosophie naturelle à neuf' [to begin natural philosophy anew] (2000: 27). The longer mid-century period between 1610 and 1665 saw a change in the languages used in mathematical texts published in France, but it was more complex than a simple instantaneous switch from Latin to French, as I will show in this thesis.

The main purpose of this thesis is to shed light on a practice that was shaped by the confluence of the trends mentioned above: the Latin and French self-translations of mathematical texts created in the middle third of the seventeenth century. 'Self-translation', or 'bilingual writing', can be understood in this context as the practice by which an author with mastery of more than one

[2] The question of the degree of mathematisation of science during the Scientific Revolution has been the subject of intense debate, as has the notion of the Scientific Revolution itself. For a summary of the key arguments, see the books and articles in the bibliography by H. Floris Cohen (2010 and 2016), Ciro Ferreira and Cibelle Silva (2020) and Henry (2008).

language produces the same text in more than one language. In particular, this thesis will investigate as case studies three pairs of bilingual texts composed in Latin and French by their authors: Pierre Hérigone's *Cursus mathematicus* and *Cours mathématique* (published together 1634–42), Marin Mersenne's *Harmonie universelle* and *Harmonicorum libri* (published 1636–37), and Blaise Pascal's two collections of treatises on the Arithmetic Triangle, of which only the second collection, the *Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière* (1665) was published.[3]

As case-study research into the production of self-translated mathematical texts, this thesis is situated primarily within the field of translation studies, particularly historical research into self-translation, although it clearly also intersects with the history of science and, more specifically, the history of mathematics, and with the history of the book. Despite the recent increase in interest in self-translation, very little research has been undertaken into the self-translation of mathematical texts in any era or culture, including mid-seventeenth-century France, in any of these fields. As I will show in chapter 1, the majority of self-translation research has focused on twentieth and twenty-first century literary texts. Research into pre-twentieth-century self-translation, including Jan Hokenson and Marcella Munson's highly regarded 2007 historical survey, *The Bilingual Text: History and Theory of Literary Self-Translation*, has continued the focus on literary texts. While it is not the case that there have been no investigations into bilingual mathematical texts, the few available studies originated in the fields of either the history of mathematics or literary studies. My research will therefore contribute to research in translation studies, particularly in the area of self-translation of pre-twentieth-century non-literary texts, the history of mathematics and the history of the book.

Building on further research by Hokenson (2013) into understanding self-translators in their own specific historical milieu, I will argue in this thesis that the decision taken by Hérigone, Mersenne and Pascal to write the case-study works as bilingual texts and their practices in doing so were the result of a range of historical and personal factors: the changing relationship between Latin and French in French society, particularly in scientific and mathematical writing,

[3] As will be seen in chapter 5, Pascal's treatises on the Arithmetic Triangle were written and printed by 1654, but none were published until after this date.

the transmission of mathematical knowledge through translation, and the ways in which these long-term trends created audiences for the texts. I will argue that, although the historical factors created the conditions for self-translation in the middle third of the seventeenth century, the mathematicians had their own specific reasons for creating their bilingual works in the ways that they did, and that these personal motives shaped very different relationships between the Latin and French versions of the three pairs of bilingual texts, relationships that I will also investigate in detail.

As a consequence of the location of this research within the field of self-translation, the principal research methods used in this thesis are taken from self-translation studies research, the main findings of which will be outlined in the first chapter of the thesis, including a full definition of self-translation. In terms of selection of the case studies, my methodology is taken from historical translation studies, which is itself largely based on case-study research. According to Jean Boase-Beier et al, case studies as a research tool spread to translation studies as a result of the popularity of descriptive translation studies in the 1990s (2018b: 12). There is therefore now general agreement that case studies as used in translation studies are 'descriptive studies grounded in the actual facts of translation' that act as 'a useful tool in the formation of theories' (Boase-Beier et al 2018b: 5). Despite their increasing popularity, however, there has been very little research into the use and impact of case studies in translation studies, apart from two articles by Şebnem Susam-Sarajeva (2001, 2009). Gabriela Saldanha and Sharon O'Brien (2013) and Boase-Beier et al (2018) have used Susam-Sarajeva's findings, together with case-study research in the social sciences, to discuss the use of case studies as a research methodology in translation studies and literary translation studies respectively.

Despite being the most common research method at doctoral level, it is Susam-Sarajeva's view that a lot of case-study research in translation studies does not discuss the actual methodology used in arriving at findings (2009: 37–38). As the origins of case-study research lie in the social sciences, Susam-Sarajeva believes that case studies in translations studies should be based on social science methodology (2009: 38). My aim in this section of the introduction is therefore to outline the methodological approach I have used to select and discuss my case studies, in the light of research within both translation studies and the social sciences. The principal issues that arise when considering the use of case-study research methodology in translation studies include its applicability to historical translation studies, the selection of cases for study, the questions to be asked when investigating the cases, and the uses that can be made of the results of the investigation, particularly their generalisability.

The question of the applicability of case-study research to historical translation studies derives from the opinion shared by Robert Yin and Bill Gillham, the two leading scholars of case-study research in the social sciences cited by Susam-Sarajeva and Saldanha and O'Brien, who believe that case studies should study human activity embedded in the real world and should only be studied in their 'current', i.e. their own, contemporary, context (Yin 2018: 15, Gillham 2000:1). Saldanha and O'Brien disagree with this view with respect to translation studies, stating that it is legitimate to use case studies to investigate translation in its historical context: they 'see no reason why the case study cannot be used in studying historical phenomena and be considered a method within the broader field of historical research' (2013: 207). This view is supported by Susam-Sarajeva, who, following Yin and Gillham, defines a case for study in translation studies as a 'product, person, etc. in real life, which can only be studied or understood in the context in which it is embedded' (2009: 40). Within historical case studies, however, she believes that 'real life' refers to the fact that 'the texts exist in the here and now' and are therefore legitimate subjects for case-study research (2009: 40, note 6). I believe this adaptation of social sciences case-study research approaches for use in translation studies is reasonable and therefore provides a satisfactory justification for using case studies in this investigation into self-translation in seventeenth-century France.

The second question concerning the use of case studies in translation studies research relates to case selection. This involves decisions about the number and type of cases and the selection of the actual cases themselves. In order to investigate phenomena in their context, case-study researchers in the social sciences are careful about how they select their cases. This approach is replicated in translation studies case-study design. According to Yin, case studies in the social sciences may investigate either single or multiple cases (2018: 47–61). As their names suggest, single-case studies involve investigation of a single instance of a phenomenon, whereas multiple-case studies examine a number of similar cases with common characteristics. Yin suggests that '[t]he evidence from multiple cases is often considered more compelling [than single-case studies], and the overall multiple-case study is therefore regarded as being more robust' (2018: 54). According to Inge Bleijenbergh, it is important that the multiple cases are discussed separately before their specific features are compared and common patterns and explanations sought (2010: 61). The differentiation between single-case and multiple-case studies has been transferred into translation studies and accepted as valid methodology. Susam-Sarajeva suggests that single-case studies are the rule in translation studies despite the relative lack of justification for undertaking them when compared with the benefits of multiple-case studies. She concludes that 'multiple-case studies have considerable advantages over single-case studies in terms of the rigour of the conclusions which can be derived from them' (2009: 43–44). In addition, in translation studies, she believes, 'multiple units of analysis command interest because they can be comparative in their emphasis on similarities and contrastive in their emphasis on differences' (2001: 175). Therefore, in order to be in a position to compare and contrast my findings and draw robust conclusions, I have chosen to include three cases of self-translation involving Latin and French versions of mathematical texts created by three different authors between 1634 and 1654 rather than simply examining a single pair of texts or multiple texts by a single author.

Once a decision has been made to use either a single case or multiple cases, the next step is to select the cases themselves. In the social sciences, a distinction in methodological approaches to selection is made between approaches that seek quantitative data, such as surveys, and those that produce largely qualitative data, such as case studies. According to Bleijenbergh, subjects for survey research are best chosen randomly, while a strategic approach is the preferred means of selecting cases for case-study research, as it allows researchers to collect the maximum amount of information about the specific characteristics of the phenomenon being studied (2010: 61). This approach is supported by Susam-Sarajeva, who concludes that, if translation studies researchers wish to draw general conclusions from their research ‘[t]his can be done not by random sampling, but only by theoretically informed decisions and the use of existing information’ about the object of research (2009: 52). Susam-Sarajeva’s argument is persuasive, particularly as, in my research, there are very few cases from which to sample. Appendix 1 shows that I was able to find just nine pairs of bilingual mathematical works published in France between 1610 and 1655, of which eight were Latin and French self-translations and the ninth a Dutch-French pairing. In addition, two, including the French-Dutch self-translation, consist of logarithmic and trigonometric tables accompanied by short treatises on how to use the tables in calculations. Of the remaining seven Latin-French pairs of texts, three have a common thread running through them: development of knowledge regarding combinatorics (permutations and combinations) and the Arithmetic Triangle.[4] Those are consequently the three pairs of texts that I have chosen as my case studies.

The third issue in case-study research is the types of question that should be asked when investigating the selected cases. Yin believes that case studies are the preferred strategy in the social sciences when asking questions about ‘how’ and ‘why’ something occurs (2018: 2). Susam-Sarajeva believes ‘[t]he “how” and “why” questions are similarly crucial [...] for case study research in translation studies’ (2009: 40). Boase-Beier et al agree with this perspective, arguing that contextualisation (the ‘why’) allows case studies to take into account a range of factors related to a given text, including the author’s environment and the audience for the text (2018b: 14). Although he does not specifically take into account case-study methodology, the ‘why’ aspect of Yin’s approach fits well with Anthony Pym’s contention that ‘translation history should explain *why* translations were produced in a particular social time and place’ (1998: ix). The approach I intend to take in this thesis fits well with both case-study and translation history methodologies as described above: as will be seen in chapter 1, historical research in self-translation focuses on how self-translators operate when translating their own work and how their actions can be explained by the social and historical factors operating in the time and place in which they live and work. My research will begin by identifying *what* was self-translated and *when* it was self-translated by locating the pairs of case-study

[4] Full information on combinatorics and the Arithmetic Triangle (commonly known as Pascal’s Triangle) can be found in appendix 2.

texts within each writer's wider works, before going on to investigate *why* the mathematicians decided to create their texts as bilingual works and to compare in detail aspects of the pairs of texts to determine *how* the self-translation was carried out, particularly in terms of the similarities and differences between each version of the texts.

The final question for consideration involves conclusions that can be drawn from the results of case-study research. The lack of random sampling in the selection of cases for study and the reliance on qualitative rather than quantitative data have implications for the generalisability of any results obtained in the case studies. Within the social sciences, it is felt that any conclusions from case studies cannot be generalised to the wider population from which the objects of study have been drawn (Suram-Sarajeva 2009: 44–53). Instead, the consensus is that conclusions should be restricted to general comments about the phenomena described within them. As Saldanha and O'Brien suggest with regard to case-study research in translation studies, 'it is not useful to force case studies to stand for realities larger than themselves' (2013: 233). My intention is therefore to reach conclusions on each of the pairs of texts separately and then to look for common and contrasting findings. In so doing, I will be seeking, in the words of Ruthanne Tobin, to use my descriptive case study 'to reveal patterns and connections, in relation to theoretical constructs, in order to advance theory development' (2010: 288). In an under-studied area of translation studies research such as that covered in this thesis, it is likely that, as Saldanha and O'Brien suggest, my case studies will 'challenge established theories and [...] may point to the need for a new theory in areas that have not received sufficient scholarly attention' (2013: 210). I will not be suggesting that my findings, either at the level of the individual authors and texts, or when all three authors and their texts are considered together, can be extrapolated to the wider contexts of all self-translated mathematical texts in the period under investigation, or all such texts in a wider or altogether different period or place. In statistical terms, the most relevant populations to which I could generalise the results would be considered too small for extrapolation, particularly the corpus of eight pairs of Latin and French texts from the middle third of the seventeenth century. I will, however, be suggesting that the three case studies investigated here may help to bring about reflection on future avenues for research.

The first two chapters of my thesis serve as an introduction to the context in which the self-translation case studies can be understood. The thesis therefore begins in chapter 1 with an introduction to the most relevant questions in current research into self-translation as they relate to the three case studies. Chapter 2 outlines the key factors in mid-seventeenth-century French society that contributed to the self-translation of mathematical texts. These contextual chapters are followed by the three case studies, which are presented in chronological order of composition: Hérigone's *Cursus mathematicus* and *Cours mathématique* in chapter 3, Mersenne's *Harmonie universelle* and *Harmonicorum libri* in chapter 4, and Pascal's two collections of treatises on the Arithmetic Triangle in chapter 5. This order has been chosen in order to trace the development of the seventeenth-century understanding of combinatorics, and the Arithmetic Triangle in particular.

Each of the case studies will follow the same general pattern, in order best to answer the 'what', 'when', 'why' and 'how' questions, as outlined above. Each chapter will begin by situating the self-translation within the author's life and works and within the production of seventeenth-century mathematical texts, in order to consider his motivation for creating the bilingual work and his practice in doing so. Investigation of each mathematician's writing will be undertaken at two levels. First, there will be a brief examination of the entire bilingual work as a self-translation, focusing on the overall structure of the work and any other factors that are specific to it. The limited nature of this evaluation of the works in their entirety is a necessary restriction caused by the length of Mersenne's and Hérigone's works.[5] The length of these works therefore means that close analysis of each author's translation practice needs to take as its basis shorter sections of text. Consequently, each case study will finish with closer examination of the main section in each work that deals with the mathematics of combinatorics and the Arithmetic Triangle: Hérigone's book on practical arithmetic in the second volume of his work, Mersenne's books on melodies and songs, and Pascal's principal treatises on the Arithmetic Triangle.

[5] Hérigone's six largely bilingual volumes contain 3418 pages of main text, while the main text in Mersenne's two books contains a total of 1808 pages (1448 in the French volume and 360 in the Latin version).

Chapter 1

Self-translation: an introduction

The account of the history of self-translation and research into bilingual writing provided in this chapter will serve to define the practice, locate early seventeenth-century mathematical self-translation within a wider historical context and demonstrate its absence from self-translation research. In a definition that was frequently cited in early self-translation research and is still often mentioned today, Anton Popovič characterised self-translation as 'the translation of an original work into another language by the author himself' (1976: 19). As an area of research, self-translation originally grew out of literary studies of modern bilingual writers such as Samuel Beckett (1906–1989) and Vladimir Nabokov (1899–1977), and it is from literary studies that Popovič's definition comes. As I will demonstrate in section 1.1, the definition of self-translation has developed to incorporate understanding of self-translation as a bilingual practice that is also common to other genres and periods and may involve the simultaneous creation of two versions of a work as well as translation from one version to the other. Throughout this thesis, I will be using a more detailed set of definitions of the process, product and producer of a self-translation, synthesised from the research of a range of self-translation scholars. I define self-translation, or bilingual writing, as the process by which a single identifiable individual, known as the self-translator, or the bilingual, bicultural author, produces two versions of the same text in different languages. The texts may be composed simultaneously, near-simultaneously or consecutively and may be considered by their author as an original text and a translation or as dual originals, where the author has rewritten the first version in some way.[6]

Self-translation has a long history, which I will outline in section 1.2. Despite its status as a longstanding writing practice, however, self-translation is a new area of study within translation studies. In section 1.3, I will describe two issues within the discipline that have significant implications for my research. In section 1.3.1, I will give an account of the discussion involving the status of self-translation as a practice and discipline distinct from standard, or 'allographic'

[6] For the sake of convenience, the definition assumes that all self-translators and self-translations are bilingual, but it should be borne in mind that they could both also be multilingual.

translation (where the author and translator are two different people) and the potential impact on the study of self-translation as a separate practice. I will then go on, in section 1.3.2, to discuss the balance and spread of the authors, text-types and eras investigated in self-translation scholarship, particularly the limited amount of research into pre-modern non-literary self-translation. This will enable me to identify the gaps that my research seeks to fill.

Once the questions above have been addressed, I will outline, in section 1.4, a methodology for my research, based on existing self-translation scholarship. I will follow this section with examples taken from the limited scholarship devoted to Renaissance and Early Modern self-translation to illustrate the main questions raised by the methodological framework as they are likely to relate to my investigation. In section 1.4.1, I will examine what the existing research says about Renaissance and Early Modern writers' motivation for translating their own work, before going on, in section 1.4.2, to examine the main findings as they relate to the process and product of self-translation in the relevant periods. The chapter will conclude, in section 1.5, with an outline of the ways in which the findings set out in the earlier parts of the chapter will inform my own research in the rest of this thesis.

1.1 Defining self-translation

Very little attention was paid to self-translation for the two decades following Popovič's work in literary studies: in the late 1990s, Mark Shuttleworth and Moira Cowie stated categorically in their *Dictionary of Translation Studies* that '[l]ittle work has been done on autotranslation' (1997: 13). The lack of research into the subject was reflected in the uncertainty over the terminology available to describe it, as pointed out by Shuttleworth and Cowie: 'while the standard terms for this phenomenon are *autotranslation* and *self translation*, Popovič also refers to it as *authorized translation*' (1997: 13).[7] Rainier Grutman's article on the practice in the first edition of the *Routledge*

[7] 'Authorized translation', Popovič's alternative term for self-translation (1976: 19), should not be confused with other possible meanings of the term. Batchelor states that the 'absence of clear definition allows for a significant degree of latitude in use of the term' and notes that 'authorised translation' could suggest that a text has undergone one of four processes, which she defines: the translation has been approved by an individual or institution; a translator, editor or publisher has been appointed; an unspecified person, group of people or institution regard the translation as authoritative; the translator or editor has used the term 'authorised translation' in the translation's paratexts as a claim for authorised status (2018: 78–79). None of these four processes could be considered to be either self-translation or bilingual writing as defined in this chapter.

Encyclopedia of Translation Studies (1998) could be found under the heading of 'auto-translation'. By the time that Grutman updated his *Routledge Encyclopedia* entry in 2009, 'self-translation' (including the hyphen omitted by Shuttleworth and Cowie) had become the predominant term used in anglophone research, while 'auto-translation' had become the commonly used term, in its various versions, in studies carried out in the Romance languages.

As the terminology of self-translation became more settled, attempts were made to add nuance to Popovič's early definition. For a number of years, his was the only definition quoted in research; however, as Tiziana Nannavecchia has noted, it has been superseded as the most commonly cited definition by Grutman's statement that opens the article on self-translation in the second edition of the *Routledge Encyclopedia* (Nannavecchia 2014: 105). In the article, Grutman states that '[t]he term "self-translation" can refer both to the act of translating one's own writings into another language and the result of such an undertaking' (2009a: 257).[8] This definition has been further updated for the third edition, where Grutman states that '[t]he term self-translation can refer to *either* the *process* of translating one's own writings into another language *or* the *product* of such an undertaking' (2019: 514).[9] The sense of the definition has remained essentially the same, but the terminology of 'process' and 'product' has been introduced to reflect ongoing discussions on the importance of differentiating between process and product in research.[10] Nannavecchia has noted that the dual meaning contained in Grutman's definition also applies in other languages, particularly the Romance languages, where much current research is being carried out (2014: 105).

Other scholars have added new dimensions to Grutman's and Popovič's definitions, including Grutman himself. Among the most helpful is Hokenson and Munson's characterisation of self-translation as the production of a bilingual text 'authored by a writer who can compose in different languages and who translates his or her texts from one language into another' (2007: 1). To support this definition they have introduced the concept of biculturality, whereby the self-

[8] The wording is slightly different in the 1998 edition, reflecting the uncertainty over terminology: '[t]he terms auto-translation and self-translation refer to the act of translating one's own writings or the result of such an undertaking' (Grutman 1998: 17).
[9] I have added the italics to highlight the changes made since 2009.
[10] See, for example, Maria Filippakopoulou (2008: 19) and Michael Boyden and Liesbeth De Bleeker (2013: 180).

translator can be seen as a 'bilingual writer, living and working in two languages and cultures' (2007: 155).[11] This is echoed by Anthony Cordingley's notion of the self-translator as 'a particular kind of crosscultural interlocutor', '[w]riting at the nexus of at least two languages, two cultures and for at least two different reading publics' (2013b: 1). In this situation, self-translation as practised by the bilingual writer can no longer be seen simply as the process of producing a faithful rendering of a source text in a second language. Instead, '[b]ilingual self-translators produce two texts, often publish them under the same title, and usually consider them to be comparable versions' (Hokenson and Munson 2007: 3). This process has been described by twentieth-century Polish-American writer Isaac Bashevis Singer (1904–1991), when discussing the English self-translations of his original Yiddish works, as the creation of 'second originals' (Grutman and Van Bolderen 2014: 330). The two texts may be very different, but they are still considered by the author to be twin versions of a work, and therefore a self-translation.

In the most recent version of his *Routledge Encyclopedia* article, Grutman adds further nuance to the debate with his concept of simultaneous and consecutive self-translation: in the former practice, 'the first version is still in progress when the writer embarks on self-translating it', while in the latter, 'by contrast, the translation work begins once the original has been published or at least a final draft has been completed' (2019: 516). In simultaneous self-translation, the texts evolve together, with the potential for cross-fertilisation (Grutman 2019: 516). Julio César Santoyo notes that, in consecutive self-translation, there is the possibility of work on the second version leading to revisions to the original version (2013a: 29–30). Of the two processes, simultaneous self-translation has the greater potential to undermine notions of original and translation to create two versions of a single text, or twin originals, as suggested by Singer (Grutman 2019: 516). In both cases, one version may eventually be better known than the other, potentially overshadowing or supplanting it (Santoyo 2013a: 34). As will be seen in chapter 5, this is the case with Pascal's *Triangulus arithmeticus*, which is barely known in relation to its slightly later French version, the *Traité du triangle arithmétique*.

[11] The concept is very similar to Ann Moss's earlier description of the practice of Jean Lemaire (*c.*1581–*c.* 1650) in *La Concorde des deux langues* [The Harmony of the Two Languages] (1513), to the effect that '[b]ilingualism in the strict sense has become biculturalism' (1994: 63).

Taking Singer's notion of second originals a stage further, Susan Bassnett suggests that self-translation brings into question the very concept of an original work. Self-translation transforms the original into a draft 'in what then becomes a process of producing another version in another language' for a new readership (2013a: 288). In the process, the boundary lines between original and translation dissolve. This dissolving of boundaries between versions then raises the question of 'whether an original can be said to exist at all' (Bassnett 2013b: 20). Instead, what is created are two originals, or two versions of a single bilingual text (2013a: 287). This view is reflected in Hokenson and Munson's belief that most self-translators revel in the dissimilarities caused by the use of different languages to create 'dual texts' (2007: 11). This notion of dual texts is particularly helpful when it is impossible to decide which of the texts is the original or when the two texts are written simultaneously. Santoyo describes the latter case as a 'dynamic relationship' between the texts that 'creates a sort of complementarity between the original and its translation' (2013a: 31). These extensions of the definition of self-translation to include simultaneous or near-simultaneous self-translation and original and translation or dual originals will be particularly helpful when examining all three case-study texts. In each case study, I will discuss whether the versions were produced simultaneously or consecutively, and will explore the relationship between them.

A further consideration in defining self-translation, particularly in view of Hokenson and Munson's survey of self-translations as bilingual texts, is the relationship between the terms 'bilingual writing' (process), 'bilingual text' (product) and 'bilingual writer' (producer) on the one hand, and 'self-translation' (product and process) and 'self-translator' (producer) on the other. According to Cordingley, there exists in some self-translation scholarship a 'perceived difference' between self-translation and bilingual writing, based on 'the time between composition of source and target text' (2018: 360). The distinction rests on an assumption that bilingual writing occurs simultaneously, while self-translation only occurs consecutively. I have not found the same clear demarcation in my own research. Rather, I have been struck by what Mary Snell-Hornby describes as the failure of Translation Studies to define 'clear and unambiguous' terminology (2009: 127).

A consequence of the terminological failure observed by Snell-Hornby is that, within much self-translation research, bilingual writing is considered to be synonymous with self-translation so that self-translations are seen as bilingual pairs of texts with a single author, and self-translators are viewed as bilingual writers. Grutman, for example, implies an equivalence between bilingual writing and self-translation when he compares Catalonia's twenty-first century 'self-translators' with Belgium's mid-twentieth-century 'bilingual writers' (2009a: 258). The tendency to conflate 'bilingual writing' and 'self-translation' is particularly prevalent in research involving historical self-translation practices. Moss, for example, talks of 'self-translating bilinguals' in the Renaissance (1994: 73), while Hokenson and Munson define the bilingual text as 'the self-translated text, existing in two languages and usually in two physical versions, with overlapping content' (2007: 14). In addition, they consider the composer of the bilingual text as the 'self-translator', who is 'the bilingual writer who authors texts in one language and then translates them into the other' (2007: 12). The order in which the texts are composed may not always be clear, but 'in all cases the texts are the creations of the same writer' (2007: 13).

The discussions described above, taken from a range of different threads in self-translation research, have led me to my own, composite definition of self-translation, which I will use throughout the rest of this thesis, and which I provided in the introduction to this chapter. In creating my definition, I have taken Hokenson and Munson's definitions of self-translation and biculturality as my starting point, but I have also borne in mind Popovič's original definition, Grutman's later definition and his notion of simultaneous and consecutive self-translations, Singer's idea of second originals, and Bassnett's reminder that translation is a form of rewriting. Consequently, I define self-translation, or bilingual writing, as the process by which a single identifiable individual, known as the self-translator, or the bilingual, bicultural author, produces two versions of the same text in different languages. The texts may be composed simultaneously, near-simultaneously or consecutively and may be considered by their author as an original text and a translation or as two originals, where, in either case, the author has rewritten one version in some way to create a second. The purpose of the composite definition is to include a wide range of practices, all of which are forms of rewriting, stretching from the faithful translation of a completed work at one end of the spectrum to the simultaneous creation of two complementary, but different, dual works at the other, where the two works are, as Bassnett suggests, still clearly versions of the same bilingual work (2013a: 288). It should be noted that, unlike the simultaneous creation of bilingual texts, consecutive self-translation retains more clearly the notion of translation between source and target language texts. Although, as stated above, both translation and self-translation can be viewed as forms of rewriting, it will therefore nevertheless be useful to retain the idea of transposing a text from one language to another by means of translation (Bassnett 2014: 3), and the notions of ‘faithful’ and ‘free’ translation discussed below in section 2.1.4. I will use this narrower definition of translation in comparisons between ‘original’ and ‘translated’ texts, particularly, but not exclusively, when discussing consecutive self-translations.

Finally, the question of authorship needs to be clarified. In the definitions above, I have deliberately talked about self-translators ‘creating’ self-translations. The verb was chosen to encapsulate a range of writing practices wider than that typically encountered in twenty-first century self-translation but present in earlier centuries, including in Hérigone’s *Cursus mathematicus* and *Cours mathématique*. This bilingual text is a mixture of original writing and rewriting of compiled material originally composed by other authors, some acknowledged, the majority not, as will be seen in chapter 3. For the purposes of this thesis, then, self-translation, or bilingual writing, is undertaken by a single identified individual, where the creative process mainly involves original writing, but may also involve elements of rewriting, compilation of non-original material, collaborative writing, and other writing practices. Questions of authorship are significant within the history of self-translation, as the next section will demonstrate.

1.2 Self-translation: a history

An understanding of the history of self-translation began to emerge in the first decade of this century with publication of research carried out by Santoyo (2005, 2006) and of Hokenson and Munson’s *The Bilingual Text* (2007). Santoyo pointed out that scholars seemed to be treating self-translation as a marginal phenomenon, whereas he had uncovered a long and widespread history of the practice extending back into Antiquity (2005: 858–59). He showed that self-translation has been described by literary scholars as ‘rare enough’ (Sylvester 1963: lviii), ‘rarissimes’ [‘very rare’] (Balliu 2001: 99), and ‘not very common’ (Federman 1993: 76); moreover, it was claimed that, from a modern perspective, ‘les autotraductions sont des exceptions’ [self-translations are exceptions] (Berman 1984: 13). Self-translation was considered to consist of marginal ‘borderline cases’ and ‘abnormal or special phenomena’ (Kálmán 1993: 69). Brian Fitch seemed to be the exception to the trend, noting that ‘[i]t is not that bilingual writers are all that rare’ (1988: 13). Following these early misconceptions, perceptions have changed, according to Grutman, with the result that scholars ‘have come to realize that self-translation is neither an exceptional nor a particularly recent phenomenon’ (2013b: 189).

Indeed, as Santoyo points out, self-translation is far from unusual, as he traces examples, particularly in Europe, from the early centuries of the common era, through the Middle Ages and the Early Modern period, to a range of countries around the world in the twentieth and twenty-first centuries (2005: 859–66; 2006: 24; 2013b: 23–24). Santoyo believes that ‘[n]o estamos ante raras excepciones, sino ante un corpus inmenso […] de textos traducidos por sus propios creadores’ [we are not faced with rare exceptions, but an immense corpus (…) of texts translated by their own creators] (2005: 866). This claim does need to be seen in context, however: Santoyo himself has quantified the number of self-translations as probably being in the hundreds, perhaps over a thousand (2006: 24). Although Santoyo has not unearthed every example of self-translation, as I will show below, it is nevertheless clear that, while there are many examples of self-translation going back nearly two thousand years, this cannot really be considered an ‘immense corpus’ when set against the number of written works created during that period. Michaël Oustinoff characterises literary self-translation as a ‘phénomène relativement rare’ [relatively rare phenomenon] (2018: 83). This would seem to be a reasonable conclusion for self-translation in all genres: self-translation is a ‘relatively rare’ phenomenon rather than either a ‘rare’ or ‘common’ one.

As both Hokenson and Munson and Santoyo have shown, the roots of self-translation go back to Antiquity (Hokenson and Munson 2007: 1; Santoyo 2005: 859, 2006: 24). The earliest example cited by Santoyo is a Jewish history that Flavius Josephus (37/38–100 CE) originally composed in his native Aramaic in the first century of the common era and subsequently translated into Greek (2005: 859; 2006: 24). Santoyo and Hokenson and Munson identify the late Middle Ages and the Renaissance as a period when self-translation flourished (Hokenson and Munson 2007: 1; Santoyo 2005: 861). In the Middle Ages, self-translators generally operated from Latin into the vernacular languages, reinforced by endogenous bilingualism, which was 'a structural or systemic aspect of the diglossic speech community they grew up and were educated in' (Grutman 2013a: 71). The relationship between Latin and the vernaculars was a vertical one, where interaction generally went in one direction, as Latin was used as the medium of *translatio studii*, 'the transplantation of the study of ancient wisdom from Greece to Rome and then to Paris' (Hokenson and Munson 2007: 6). During this period, some transmission of culture and ideas also occurred on the horizontal plane, between the vernacular languages. Nevertheless, cultural exchange continued to take place in 'primarily the vertical form of translation from Latin into the vernacular' (Bolduc 2020: 42).[12]

During the late Middle Ages and the Renaissance, the relationship began to alter, as the principal vernacular Romance languages, French, Italian and Spanish, became established and began to gain authority (Hokenson and Munson 2007: 28). This resulted in 'a shift from vertical to horizontal dominance' (Stierle 1996: 56). The horizontal plane was now the 'the level zone of two-way interactions among Latin and vernacular cultures' (Hokenson and Munson 2007: 6). The changed relationship between Latin and the vernacular languages led to a rise in self-translational activity, a natural consequence, in Grutman's view, of the multilingualism of the literary environment of the time and of a desire to promote the vernacular languages as competitors of Latin (2012: 33). It is possible too that the rise in self-translation itself contributed to changes in the dynamic between Latin and the vernaculars. As will be seen in chapter 2,

[12] The concept of horizontal and vertical translation was first introduced by Gianfranco Folena. In vertical translation, 'la lingua di partenza, di massimo il latino, ha un prestigio e un valore trascendente rispetto a quella d'arrivo' [the source language, generally Latin, has superior prestige and value in comparison with the target language], whereas horizontal translation takes place between languages with strong structural similarities and cultural affinities, such as the Romance languages (1994: 12). There are clear affinities with Grutman's notion of asymmetry between dominant and dominated languages in diglossia, a connection he makes explicit in a number of articles (see Grutman 2009b, 2011, 2012, 2013a, 2013b, 2015, 2017 and, to a lesser extent, 2009a and 2019). Horizontal translation occurs when diglossia and asymmetry break down, creating the conditions for bilingualism among some sections of society.

the most important factor in Latin and French self-translation in seventeenth-century mathematics texts was the way in which the relationship between the two languages had become more symmetrical as the diglossia present in earlier centuries was disrupted by a range of societal forces, resulting in the horizontal relationship noted above, where self-translation was able to flourish .

Santoyo shows that self-translation began to increase in significance in the fifteenth century, with examples including the *De pictura* [On Painting] (1435) of Leon Battista Alberti (1404–1472) and the poems of Charles, duc d'Orléans (1394–1465) (2013b: 27–28). It then accelerated in the following two centuries: '[l]os siglos XVI y XVII contemplaron una eclosión sorprendente de la práctica autotraductora, sobre todo entre el latín (lengua mayoritaria de cultura) y los idiomas nacionales' [the sixteenth and seventeenth centuries saw a remarkable blossoming of the practice of self-translation, particularly between Latin (the principal language of culture) and the national languages] (2005: 861). During this period, a number of writers in a variety of genres wrote their works in Latin and translated them into their own vernaculars, including Jean Calvin (1509–1564), who translated his *Christianæ religionis institutio* [Institutes of the Christian Religion] (1536) into French, Thomas More (1478–1535), who produced an English version of his *Historia Ricardi Tertii* [The History of Richard III] (1513), and John Donne (1572–1631), who also translated his *Conclave Ignatii* [Ignatius his Conclave] (1611), a diatribe against the Jesuits, into English (Santoyo 2005: 862; 2013b: 28–30). As will be seen later in this chapter, there are many more examples that could be cited. It is notable that, although Santoyo states that most seventeenth-century self-translation was non-literary (2013b: 30), his surveys include very few instances of scientific or mathematical self-translation: he does not include any of the nine cases highlighted in appendix 1, including the three case-study translations, or other examples of mathematical self-translation highlighted by scholars, including those carried out in the sixteenth century by Oronce Fine (1494–1555) and Jacques Peletier (1517–1582) (Cifoletti 2014) and Juan de Ortega (*c.*1480–*c.*1568) (Marquant 2016).[13]

[13] Among the few examples of scientific or mathematical self-translation that Santoyo provides from all eras are the mediaeval mathematician Abraham bar Hiyya ha-Nasi (*fl.* before 1136), who translated his own Jewish mathematical encyclopaedia from Arabic into Hebrew, and Nicole Oresme (*c.* 1320 to 1325–

Since the sixteenth and seventeenth centuries, Latin has all but disappeared in self-translation as its use in society as a whole has diminished (Santoyo 2013b: 30). The examples Santoyo cites from the eighteenth to twentieth centuries, both literary and non-literary, generally involve self-translation from one European language to another (2005: 862–63). The range of self-translations published in the twentieth and early twenty-first centuries also includes authors creating works in both their own less widely spoken mother tongue and a major world language (2005: 863–64). In recent years there has been a vast increase in the amount of self-translation outside literary genres, particularly in academic work. In most cases, English, as the modern *lingua franca*, is the target language, to the extent that estimates suggest that the majority of scientific meetings, conferences and publications take place in English (Montgomery 2009: 7). Scott Montgomery has discovered that non-English-speaking scientists engage in a range of activities to pass on their research, including full and partial self-translation of articles, academic papers and books (2009: 9–10). The modern relationship between a dominant English and other languages demonstrates the asymmetry in status that can often be seen in self-translation, in this instance at the global level (Grutman 2013a: 73–74; 2015: 19).

1.3 Self-translation studies: a new discipline

As noted above, self-translation began to emerge as a discipline within research into twentieth-century literary bilingual writing. As recently as 1998, the research focus was still very narrow, even within literary studies. Grutman noted in 2013 that, when he wrote the entry on ‘auto-translation’ in the first edition of the *Routledge Encyclopedia*, he became aware of how little research there had been into self-translation by literary scholars other than as part of studies of well-known bilingual writers (2013: 188–89). As Fitch commented at the time of his study of Beckett’s work: ‘direct discussion or even mention of self-translation is virtually non-existent in writings on theory of translation’ (1988: 21). It has become increasingly apparent that, while this literary research generated a lot of valuable scholarship, it only provided a partial representation of self-

1382), who translated his own books on currency and economics from Latin into French in the fourteenth century (Santoyo 2005: 860; 2012: 65, 69).

translation and did not shed sufficient light on its wider significance as a cultural phenomenon (Boyden and De Bleeker 2013: 178; Grutman 2013b: 189).

Recent years have seen an increase in academic interest in self-translation. A rise in the number of publications was evident in the first decade of this century, after Grutman's first entry in the *Routledge Encyclopedia* (Boyden and De Bleeker 2013: 179). However, despite all of this activity, Simona Anselmi was able to write, as recently as 2012, that research into self-translation was 'a newly established and rapidly growing sub-field within translation studies' (2012: 11). The same year, the third edition of Lawrence Venuti's standard work on translation, *The Translation Studies Reader*, contained no reference to self-translation; as Anil Pinto has pointed out, this was true of all major translation studies texts apart from the *Routledge Encyclopedia* (2012: 68). The following year, moreover, Cordingley asserted that '[t]he self-translator has been [...] relatively neglected' (2013b: 1). Since then, there has been an increase in the number of special issues devoted to self-translation published by journals across Europe and, occasionally, further afield. The increased activity is further reflected in the large number of recent conferences, particularly in Italy and Spain (Grutman 2019: 515). Consequently, while until relatively recently self-translation was considered to be of marginal interest in translation studies, a consensus seems to have grown that it deserves much wider study because '[t]ranslation scholars now believe that self-translation is [...] much more pervasive than is commonly thought', both historically and in modern society (Boyden and De Bleeker 2013: 177). Evidence from Eva Gentes's regularly updated bibliography of self-translation research seems to suggest that, in terms of numbers of studies published, self-translation has become an increasingly fertile ground for research since the turn of the millennium.[14] Two issues that have been raised as a consequence of the increased interest in self-translation as an area of research are of particular relevance to this thesis: the question of whether self-translation should be

[14] The 39th and most recent edition of the online *Bibliography: Autotraduzione / Autotraducción / Self-translation* (July 2020), which is generally updated four times a year, though not in 2020, contains approximately 260 books or publications on the subject of self-translation from before 2000, mostly from the 1990s, and almost 500 for the first decade of this century, at an average of around fifty per year. This has increased since 2009, with between seventy and a hundred books and articles published in most years, 2013 being the exception, with over a hundred and thirty published. Gentes also lists several of the special issues and conference presentations on self-translation mentioned above.

studied as a discipline in its own right and the matter of the lack of balance in the genres and eras researched by scholars in the field.

1.3.1 Why study self-translation at all?

The question of self-translation's position within translation studies has been raised at various times in the last decade by a number of leading translation studies scholars, including Oustinoff and Bassnett. Their position can be summarised in the following question: is self-translation a sufficiently distinctive phenomenon to warrant separate study within translation studies? Central to the debate is the question of whether self-translators have more freedom in the way they translate their works than allographic translators (Boyden and De Bleeker 2013: 180). The assumption in early self-translation scholarship was that self-translators are necessarily freer than allographic translators to alter the source text because of their closer relationship to it (Fitch 1988: 125). This led to the important question of whether the evidence supported this assumption of greater freedom. Opinion on this matter ranges across the full spectrum, according to Boyden and De Bleeker (2013: 180).

At one end of Boyden and De Bleeker's spectrum, Helena Tanqueiro believes that, although self-translators have the freedom to make changes of some types, in reality they 'see themselves more as translators than authors when they translate' (2000: 59). In the most recent edition of the *Routledge Encyclopedia*, Grutman summarises this position by saying that textual evidence shows that 'self-translators come up with solutions that for the better part can be shown to be common to all translators' (2019: 517). Shlomit Ehrlich, for example, found that South African novelist André Brink (1935–2015) 'followed conventional translation procedures rather than carve out a different translation approach' in creating the English version of his own *Kennis van die aand* [Looking on Darkness] (1973) (2009: 243). The opposite view to Tanqueiro's 'holds that self-translators are not like translators at all but more like authors rewriting their own work' (Boyden and De Bleeker 2013: 180). Hokenson and Munson found, for example, that '[t]he tradition of the bilingual text since antiquity suggests [...] that many bilingual authors [...] see themselves as recreators producing a new original model of the old' (2007: 199).

The apparent divergence in perception between the view of the self-translator as recreator or as faithful translator of his or her own work is, however, more apparent than real if all translation is seen as a form of rewriting. As Anselmi notes, a number of translation studies theories treat all translation as a form of rewriting where a new text is produced in a new cultural system, thereby making it 'difficult to see how the self-translating author has more freedom than an allographic translator' (2012: 24). Oustinoff takes this thinking a step further, suggesting that all translation, whether allographic, co-created with the author, or undertaken by the author alone, 'constitue [...] une version à part entière de l'œuvre dont elle dérive' [forms (...) an integral part of the work it derives from] (2018: 84). In other words, both allographic translations and self-translations of a writer's work form part of the writer's complete works, alongside original texts. The logic of this argument culminates in Bassnett's question, posed in 2013: 'How useful is the term "self-translation" in any case?' Her argument is that 'if all translation is a form of rewriting, then whether that rewriting is done by the person who produced a first version of a text or by someone else is surely not important' (2013a: 287).

In fact, close reading of the arguments made by Tanqueiro and Ehrlich show that their perception of the self-translator as no different from an allographic translator is based on the tacit assumption that all translation is rewriting. Tanqueiro, for example, suggests that the self-translator 'may well decide to add to the work in some way since he still maintains his status as an author' (2000: 59). Similarly, Ehrlich states that Brink 'found it necessary to do what other translators do: to omit, to add, to explicitate and to tone down' (2009: 244). Where the arguments put forward by Tanqueiro and Ehrlich differ from those made by most other scholars is in their apparent refusal to see self-translation as a creative act: Tanqueiro, for example, believes that the act of creation is over when the original version of the text is completed; all that remains is to translate the work, just as for ordinary (i.e. allographic) translators (2000: 59). Bassnett takes her to task over this viewpoint, suggesting that she ignores the writer's impulse to revise and reshape their work (2013b: 287). As will be seen throughout this thesis, Tanqueiro's conclusion only occasionally reflects reality: self-translation practice covers the full range from faithful reproduction to large-scale reconfiguration of the source text.

If we accept, as I do, that all translation is a form of rewriting, and that this therefore applies to self-translation as much as it does to allographic translation, Bassnett's point still needs consideration: should self-translation be considered separately from allographic translation? Bassnett continues her argument by stating that '[w]hat matters are the transformations that the text undergoes, the ways in which it is reshaped for a new readership' (2013a: 287). She is clearly correct in this assertion. However, I would argue that what also matters is to investigate whether the transformations made in reshaping the text for a new readership are carried out in the same way by self-translators as they are by allographic translators. By seeing all forms of translation as rewriting and not investigating different approaches taken by different types of rewriter, we risk missing nuances in approaches to translation and transformation of the text that we might otherwise detect. Moreover, it is important to remember that, like translation, self-translation is a means to an end and not an end in itself. In this way, as noted above in the discussion on definitions of self-translation and bilingual writing, self-translation can be seen as one writing practice among many, and one that overlaps with others. Within my investigation this will bring into play consideration of genre, particularly mathematical treatises and compilations, as well as reflections on style, particularly mathematical writing styles and the use of proof and rhetoric in mathematical writing.

The possibility of being left with an incomplete understanding of self-translation also lies at the heart of another key issue within self-translation scholarship: whether the concentration on twentieth and twenty-first century literary self-translation and the lack of balance and spread of self-translation research that this implies means that our understanding of self-translation is skewed and patchy. In the next section, I will examine the implications of this question for understanding pre-modern self-translation, the part of the discipline where my research sits.

1.3.2 Research into pre-modern self-translation

While there has been a significant increase in the number of books, articles, special editions, and conferences on the subject of self-translation, as noted above, the vast majority have been devoted to modern literary self-translation.[15] This is almost certainly a reflection of self-translation's origins in literary studies, as also noted above (Anselmi 2012: 19; Boyden and De Bleeker 2013: 177–78). It is also significant that, despite the increase in published research, even within literary self-translation scholarship, Hokenson and Munson's historical survey of literary self-translation, published in 2007, is widely seen as 'the only consistent attempt to arrive at a panoramic overview of self-translation across the ages' (Boyden and De Bleeker 2013: 178). Despite Hokenson and Munson's overview, most literary scholarship does not concern itself with self-translation before 1900. Hokenson and Munson attribute this lack of attention to self-translation before this date to a number of factors, including the importance of national languages and national canons in building nation-states (2007: 1–2). Also significant is the difficulty in defining translation and attributing self-translations in the Middle Ages, an issue also noted by Anna Maria Babbi (Hokenson and Munson 2007: 32; Babbi 2011: 385). Changing trends in the Renaissance, such as greater emphasis on attribution to a single author and translator and on audience reception, meant that self-translators could be more easily identified (Hokenson and Munson 2007: 32). This may explain why more self-translation case studies from before the eighteenth century in Gentes's *Bibliography* investigate instances of self-translation during the Renaissance than in the Middle Ages. This is, however, relative: as noted above, there are far fewer studies of all pre-twentieth century self-translation than there are of individual twentieth-century authors. Over twenty-five years ago, Moss warned that Renaissance scholars were 'in danger of putting to the margins of our thinking the fact that most writers of the period were bilingual in Latin and a vernacular language' (1994: 61). Yet Sara Miglietti is correct to observe that, despite Moss's warning, 'Renaissance self-translation is still to a large extent uncharted territory' and that few of the recent large number of publications on self-translation 'deal even marginally with the early modern period' (2019: 214). As welcome exceptions, she notes Hokenson and Munson's text and the collection edited by Marcial Rubio Árquez and Nicola

[15] Gentes's *Bibliography* (July 2020) includes almost 1600 published books and articles on self-translation. Of these contributions, the vast majority involve research into literary self-translation created in the twentieth and twenty-first centuries. Only approximately 6% of the research identified (95 books or articles) deals with self-translation before 1700, and is spread between a number of general overviews on the one hand and studies of more than fifty self-translating writers on the other. This compares with almost 200 articles dedicated in whole or in part to Beckett, who is the most frequently studied self-translator.

D'Antuono (2012), both of which 'include chapters on Renaissance self-translation' (2019: 214, note 6).

Hokenson and Munson's observation regarding mediaeval self-translation also does not explain the lack of studies dealing with writing in the seventeenth century, when Hérigone, Mersenne and Pascal were writing: in my research I have only been able to find a small number of case studies of seventeenth-century self-translators, investigating the work of the philosopher Thomas Hobbes (1588–1679), chemist and physiologist Jan Baptista van Helmont (1580–1644), Pascal himself, and poets Donne, Daniël Heinsius (1580–1655), Constantijn Huygens (1596–1687), Stanisław Herakliusz Lubomirski (1642–1702) and Sor Juana Inés de la Cruz (*c.* 1651–1695).[16] As Tom Deneire notes at the beginning of his study of Heinsius's work, in comparison with self-translation practices in modern authors, '[c]onsiderably less attention has been paid to the occurrence of the phenomenon in Early Modern literature, which is surprising considering the largely bilingual culture of the time' (2013: 61).

The focus in research on modern self-translation means that a dearth of investigations into seventeenth-century self-translation does not constitute the only gap in research. As Trish Van Bolderen has observed, the continued domination of literary self-translation means that 'very little ha[s] been said or done about self-translation of scientific and technical texts' (research cited in Nannavecchia 2014: 107–08). This is, however, not a phenomenon that is restricted to self-translation alone: Fransen has noted more generally that '[t]he main focus of scholars of Translation Studies has been literary translation and translation theory', with the result that 'scientific texts [are] relatively understudied' (2017a: 5–6). Of the five articles I have identified that deal, either in whole or in part, with Early Modern and Renaissance science, two are

[16] This does not, of course, mean that no other studies exist, simply that I have not succeeded in locating them. It should, however, be noted that my list includes all of the small number of studies of seventeenth-century self-translation in Gentes's *Bibliography*, along with only five others. Two of the additional case studies I have identified — involving Donne and Sor Juana — are implicitly included in Gentes's survey as they form part of Hokenson and Munson's work, but Eric Nelson's investigation into Hobbes's self-translation of the *Leviathan* (1651), the author's work on society and government, and Dominique Descotes's research into Pascal are not included at all. These latter two examples suggest that there may be other works on seventeenth-century self-translators outside the field of self-translation that do not appear in the bibliography (Gentes relies on information provided by interested scholars; presumably the articles have not yet been brought to her attention). The final case study is Sietske Fransen's investigation into van Helmont's translation practices, which had not been published in time for inclusion in the version of Gentes's survey consulted.

Fransen's 2020 article about van Helmont's self-translation of a medical text and Miglietti's 2019 treatment of the self-translations by Antoine Mizauld (1510–1578) of his own astrometeorological works. The other three deal with mathematics: Descotes's article on Pascal's treatises on the Arithmetic Triangle, Hugo Marquant's article on de Ortega's sixteenth-century self-translation into Italian of his Castilian manual of commercial arithmetic, and Giovanna Cifoletti's account of Fine and Peletier's sixteenth-century bilingual textbooks.[17]

It is clear from the above that the increase in research activity in self-translation witnessed in the last two decades has not led to a noticeable broadening of subject matter: the focus on modern literary self-translation has been maintained. Consequently, there are large gaps in research, as noted in the introduction: investigations into non-literary works in all eras, including the modern era, and significant numbers of literary works from before the twentieth century. My research, with its focus on an under-studied subject (self-translation of mathematical texts) and an under-researched century (seventeenth-century self-translation) will clearly go some way to filling the lacunae.

The lack of studies on self-translation outside the dominant area of twentieth and twenty-first century literature is one significant part of the discipline that clearly needs addressing. Another area troubling self-translation scholars is the question of self-translation methodology. Hokenson and Munson, for example, comment that '[t]heoretical reflection on the bilingual text has been largely scattered and fragmentary' (2007: 10). A number of researchers have begun to sketch a possible framework for investigating self-translation, the main points of which I will outline in the next section.

1.4 A methodology for self-translation research

There is a perception among self-translation scholars that study of the field lacks a unified theory. Valeria Sperti is not concerned by this state of affairs, seeing it as inevitable in a new discipline where 'la systématisation théorique est encore en cours, chaque autotraducteur constituant, pour son plurilinguisme et son histoire, un cas à part' [the creation of a theoretical system

[17] While Miglietti's and Marquant's articles are included in Gentes's *Bibliography*, Cifoletti's work is not. Note that, in her article, Cifoletti refers to Fine as Finé; Fine is the preferred spelling of the *Dictionary of Scientific Biography*.

is still underway, with each self-translator forming a separate case with their own multilingualism and history] (2017). Boyden and Lieve Jooken believe, however, that self-translation theory has focused too much on a small number of specific case studies and needs to take a wider view (2013: 245). This need for a broader focus is supported by Grutman and Van Bolderen, who suggest that '[w]hat we have now is an ever-increasing number of individual studies which do not yet allow us to characterize the precise nature of the product of self-translation' (2014: 330).

A number of scholars have made initial general suggestions about what a methodology for analysing self-translation might look like. Grutman, for example, identifies four main areas of investigation that can be characterised as the 'when', 'what', 'why' and 'how' of self-translation (2009a: 257–58, 2019: 515–17).[18] The first question relates to the stage in a writer's career when self-translation is undertaken. Grutman proposes that, having identified when authors decide to translate their own works, researchers should delve more deeply by investigating whether a self-translation is an isolated or repeated act, whether the direction of translation between languages is always the same, and how long the gap is between versions of the text. In the latter case, consideration should be given to whether the self-translations are simultaneous or consecutive. Grutman also recommends that, alongside exploration of the 'when' of self-translation should come investigations into the 'what', i.e. a study of the types of texts an author self-translates, to see if a pattern emerges (2009a: 257, 2019: 516).

The final two questions, relating to self-translators' motives for creating a second version of their work (the 'why'), and the questions of how they go about doing it and what the finished product looks like (the 'how'), have been addressed in more depth than the other questions. The question of self-translators' motivation is summarised by Grutman as: '*why* do some writers choose to repeat what they have already written in another language?' (2009a:

[18] The 'how' and 'why' clearly fit with Yin and Susam-Sarajeva's rationale for the use of case studies, as outlined in the introduction. The 'what' and 'when' questions are an intrinsic part of research into self-translation and precede the main 'how' and 'why' questions. Grutman also touches on the 'who' of self-translation, noting that self-translation 'is no longer considered the exclusive preserve of a handful of particularly gifted polyglots', and the 'where', as '[s]elf-translators can be found on every inhabited continent' (2019: 514–15). He does not, however, suggest that these should be specific areas of investigation; in most case studies, the 'who' and 'where' questions generally form part of the background information and so are rarely discussed explicitly.

257). The recommended approach in the discipline is historical. For example, Hokenson and Munson state that 'the critical method must [...] be interdisciplinary, tracing [...] issues through the wider cultural, historical, and philosophical currents of the periods [under investigation]' (2007: 4). This approach is echoed by Grutman and Van Bolderen, who recommend examining self-translations in their historical context, comparing an author's approach with writers from the same period in time who are writing in the same genre (2014: 330). This might include, for example, consideration of questions of authorship: Blair notes that 'intellectual work in Early Modern Europe [was] often social and collaborative' (2014c). As I will show in section 1.4.1 below, this collaboration extends to self-translation in some instances. Hokenson outlines a method that could be used for dealing with the motives of self-translators in historical studies of self-translation, suggesting that it is helpful to look at self-translators' activity at both the macro, historical level and the micro, cultural level (2013: 44). She defines macro-level forces as impersonal social forces that are beyond the control of the author, are 'inherited unwittingly', and are the same for all members of a given society (2013: 44). Micro-level forces, on the other hand, are defined as personal, private motivations that may differ from individual to individual (2013: 40, 44).

The final methodological question relates to the process by which self-translators arrive at their finished product. As Boyden and De Bleeker have noted, much self-translation research has elided questions of process with descriptions of the finished product, with the result that there is far more of the latter than the former (2013: 180). The reason for this is almost certainly the fact that the easiest way of describing the process of self-translation is in terms of the outcome of a self-translator's decisions and actions. In many cases, this tends to be at the level of differences in language and structure; according to Hokenson and Munson: 'most critics ably describe the dissimilarities between the two versions of a bilingual text' (2007: 4). They suggest a more rigorous approach: '[b]ilingual analysis must [...] begin at a level more basic than current binary theoretical models of "gaps" between texts, languages and cultures. One must start from a point closer to the common core of the bilingual text, that is, within the textual intersections and overlaps of versions' (2007: 4). This is a plea to consider linguistic similarities as well as differences but also to go further and examine commonalities in terms of the two cultures inhabited by the self-translator.

Clearly, the questions raised above do not constitute a complete methodological framework; they do not allow, for example, the creation of typologies of self-translated texts of the kind formulated by Oustinoff, Santoyo or Maria Recueno Peñalver (cited in Cordingley 2018: 359–60). The questions do, however, help establish a methodology that will be useful both in examining relevant existing research into self-translation and in determining the parameters for my own research. They also create a framework that is sufficiently flexible in its applicability to a wide range of contexts and periods for it to be used by other self-translation scholars, thereby advancing research in the field. The next two sections will apply the methodological framework to examine the most important questions raised above, using examples from research into Renaissance and Early Modern translation: when do writers translate their own work, what do they choose to translate, why do they choose to do so, how do they go about doing it, and what does the finished product look like? To reflect the difficulty noted above in separating questions about *how* self-translators create two versions of their works from matters relating to comparisons between the completed versions, the process and finished product will be examined together in section 1.4.2, and will be preceded by consideration of the other questions in section 1.4.1.

1.4.1 When and why do writers translate their own work?

Despite Grutman's recommendation, there is very little explicit discussion in research literature about the specific time in writers' careers when they decide to translate their own work or about the type of work they choose to translate. This is as true of research into Early Modern self-translation as other scholarship. Miglietti's study of Mizauld's works is something of an exception in this regard: she notes that Mizauld translated at least five works on astrometeorology, all in the 1540s and 1550s, but none of his other works on other subjects (2019: 218). Potential reasons for his decision to translate his works on astrometeorology include the fact that self-translation was already well established in the field and the fact that Mizauld was early in his career and was attempting to build his reputation (2019: 218–19). Miglietti also notes that all of the translations were from Latin to French, and never in the opposite direction, as part of Mizauld's mission to vernacularise astrometeorology (2019: 217).

In contrast to discussions of when and what self-translators choose to translate, there is widespread consideration of self-translators' motivations for doing so. The three major reasons, highlighted by Grutman and Anselmi, are: the wish to reach a wider audience, the desire to promote a minority or lower prestige language, and dissatisfaction with, and distrust of, translations by allographic translators (Grutman 1998: 18, 2009a: 257–58, 2019: 516; Anselmi 2012: 33–55). Research into Renaissance and Early Modern self-translation reveals another motivation: the desire to be remembered by posterity. The research also highlights a feature of self-translation that is particularly relevant to Pascal's case: the use of self-translation to update a work.

The most frequently mentioned motivation in studies of Renaissance and Early Modern self-translation is the desire to disseminate ideas to a larger audience. This is true for works originally written in both Latin and the vernacular languages. Mario Turchetti believes that Jean Bodin (1530–1596) chose French for the first edition of his *Six livres de la République* [Six Books on the Republic] (1576) in order to support the monarchy, but subsequently translated it into Latin in order 'to reach a wider and more intellectual audience, European in scope' (2012: 110). Similarly, Francesco di Teodoro believes that the decision by Daniele Barbaro (1514–1570) to translate his Italian commentary on the *De architectura* [On Architecture] (1556) of Vitruvius Pollo (early first century–25 BCE) into Latin in 1567 'rivela il desiderio di raggiungere un pubblico più vasto di quello italiano' [reveals the desire to reach a wider audience than the Italian one], the new audience being constituted of 'gli uomini colti delle nazioni europee' [the educated men of the European nations] (2012: 221).

Translations from Latin to vernacular languages also allowed a work to become available to a wider, increasingly educated national audience: '[i]n early modern times, [...] self-translation from Latin into one of the state-sponsored vernaculars was an important way of reaching out to new elites' (Grutman and Van Bolderen 2014: 325). Such was the case with Donne, for example: Hokenson and Munson argue that he produced *Ignatius his Conclave,* the

English version of *Conclave Ignatii*, in 1611 in order to double his audience and create greater awareness of his arguments amongst the non-Latin-speaking educated elite (2007: 102). Miglietti detects a similar desire to increase the reach of his work in Mizauld's self-translations: in his case, self-translation was part of a desire to vernacularise knowledge (2019: 222). Vernacularisation was not always successful, however: Fransen has found that van Helmont's *Ortus medicinæ* [The Rise of Medicine] (1648) was more eagerly awaited among scholars than the Dutch version, *Dageraad* [Daybreak] (1644), which he wrote in the vernacular to increase access to knowledge. The likely reason was the existence of a previously established audience for the author's previous works, which had been published in Latin (2020: 69).

Miglietti makes an important point in her delineation of audiences for Mizauld's work: self-translation allowed an author to address both a Latin-reading and a vernacular audience, and thereby 'to establish a bridge between these two worlds and to help them communicate with each other' (2019: 225). Moreover, parts of the self-translator's public belong to both audiences. Echoing Hokenson and Munson's notion of biculturality and Cordingley's concept of the 'crosscultural interlocutor' 'writing [...] for *at least* two different reading publics' mentioned above, Miglietti suggests that parts of the self-translator's audience shared the author's ability to live and work in more than one culture (2019: 219).[19] The identification of these additional potential audiences adds nuance to an apparently clear-cut division into two separate and distinct audiences. This is a question I will return to in the next chapter when I consider the question of audiences for the works produced by Hérigone, Mersenne and Pascal.

The promotion of the vernacular languages as the equal of Latin is the second reason given above for self-translation in the Renaissance and Early Modern period. This appears in two related forms in the available research: the promotion of the vernacular as a language of science and the desire to create a new poetics in the vernacular language. Cifoletti describes how Fine and Peletier translated their own Latin mathematics textbooks to elevate the status of French (2014: 193–97). Peletier's vision is encapsulated in the *Dialogue de l'ortografe e prononciation françoese* [Dialogue on French Spelling and

[19] The emphasis in Cordingley's quote is mine, the aim being to underline Miglietti's point about overlapping audiences.

Pronunciation], where he says: ‘pansez quele immortalite elles pourroént apporter a une langue, i etans redigees an bonne e vreye metode’ [think what immortality it (i.e. mathematics) could give to a language if it were written in it using a correct and true method] (1550: 117). Similar motives can be seen amongst other Renaissance writers. Having written an original text in Latin, they undertook translation in order to elevate the status of the vernacular language (Boyden and De Bleeker 2013: 179). The most frequently cited example is the work of the *Pléiade* poets in France, such as Pierre de Ronsard (1524–1585) and Joachim du Bellay (*c.* 1522–1560), described by Deneire as ‘clear examples of how an author creates a poetic vernacular style while attempting to ennoble the mother tongue by imitating ancient norms’ (2013: 62). Deneire’s study involves less well-known examples among the Dutch poets of the sixteenth and seventeenth century who took the *Pléiade* poets as their inspiration in creating humanist poetry in Dutch (2013: 62). The final reason for self-translation provided by Grutman and Anselmi is dissatisfaction with translations undertaken by other translators. Miglietti presents sixteenth-century French printer and writer Henri Estienne (1528–1598) as a ‘paradigmatic case’. She recounts how Estienne decided, as a pre-emptive measure, to translate his own *Apologia pro Herodoto* [Apology for Herodotus] (1566) in order to avoid repeating his previous experience of poor translations of his work being undertaken without his knowledge (2019: 227).

An additional reason for self-translation is a writer’s desire to be understood and appreciated by future readers. Turchetti detects in Bodin’s self-translation a wish to add to, amend and clarify his theories for posterity: Bodin was aware that translating his ideas on government and political philosophy into ‘the splendor of Latin’ would provide a link with Roman ideas on sovereignty, thereby guaranteeing that they would be taken more seriously (2012: 111, 117). Similar considerations influenced the self-translations of Francis Bacon (1561–1626) into Latin, according to Hokenson and Munson: producing versions in Latin, the ‘universal *and* eternal language’, would guarantee them a long afterlife that Bacon believed would not be the case in the vernacular (2007: 92). In a letter to the future Charles I accompanying a copy of his *De augmentis scientarum* (1623), a self-translation of the *Advancement of Learning* (1605), Bacon states that the Latin book will ‘live, and be a citizen of the world, as English books are not’ (2011b: 436).

As noted above, there is a final aspect of self-translation revealed by pre-modern research that is linked to the question of a writer’s motivation for re-creating a work in a second language: updates carried out in the second version of the text that amend and improve the work. The matter is not clear-cut, as cause and effect can be difficult to determine: does the desire to update a work lead to the decision to self-translate or do authors amend and improve their work because of the possibilities created by the decision to self-translate, seeing, as Bassnett suggests, self-translation as ‘a second chance, an opportunity to redress mistakes’ (2013a: 288). In most cases, the latter option appears to be the more likely: if the wish to update a work is the driving factor, this can more easily be performed in the language of the original text. In his study of the Italian *Commentari* (1568) and Castilian *Commentarios* (1569) [Commentaries] of Alfonso de Ulloa (1529–1570), Rubio Árquez expresses the belief that, when given the opportunity, few self-translators can resist ‘la tentación de modificar el texto original — para corregir, ampliar, etc.’ [the temptation to modify the original text — to correct, expand, etc.] (2012: 252). He characterises de Ulloa’s Castilian version as ‘la excusa perfecta para reelaborar el texto original’ [the perfect excuse to rework the original text] in order to align with the ideology, culture, and history of the new audience (2012: 252). Nelson believes that modification of the text was the strategy pursued by Hobbes in the 1668 Latin self-translation of *Leviathan*, where the author sought to ‘strengthen the case he had laid out in 1651’ in the original English text, and to remove parts of the text as a matter of prudence following the restoration of the monarchy in 1660 (2012: 126–27). Brian Vickers characterises Bacon’s desire to revise and expand his work as constant, in both English and Latin: self-translating the *Advancement of Learning* as the *De augmentis scientarum* provided him with the opportunity to incorporate excerpts and extracts from a range of his own texts in both languages, as well as to modify some sections for a new audience (1968: 202–05). The opportunity for revision and improvement afforded by the decision to rewrite a work in another language can also be seen in Pascal’s French version of the *Triangulus mathematicus*. In his case, the improvements are of mathematical significance, as will be seen in chapter 5.

Bacon's methods of working also highlight an aspect of self-translation noted in the previous section. He had a number of collaborators, including family members, supporting his work, in roles such as taking notes for him (Blair 2010: 103, 110), and so should be considered less as the sole author of his work than as the principal participant in the creation of the original works and translations. Bacon is not alone: René Descartes (1596–1650) provides a revealing insight into his working practices in the front matter of the *Specimina philosophiæ* (1644), where he states: 'Hæc specimina Gallice a me scripta, et ante septem annos vulgate, paullo post ab amico in linguam Latinam versa fuere, ac versio mihi tradita, ut quicquid in ea minus placeret, pro meo juremutarem' [After these ideas were written by me in French, and first existed seven years in the vernacular, a little later they were turned into the Latin language by a friend, and the translation was delivered to me, so that I could change according to my judgment anything that did not quite please me] (1902: 539).[20] Production of the second version of a text in Descartes's case involves editing the translation provided by a collaborator. The practice of both writers brings into question both the designation of a single 'author' of works where they, as the principal writers, worked with others to produce their works and the notion of 'self' in self-translation.

In this section, I have identified a number of reasons why self-translators produce second versions of their work in another language and have related their motivations to research findings from the sixteenth and seventeenth centuries, the period during and immediately prior to the period where Hérigone, Mersenne and Pascal were writing. I have also examined ancillary questions, including self-translation as an opportunity to improve a work and textual production, of both original and self-translation, as a potentially collaborative exercise. As I will demonstrate in chapters 3, 4 and 5, many of the motivations and practices identified — particularly the desire to communicate ideas to as large an audience as possible and the desire to improve work completed in the first language — resonate in analysis of the bilingual mathematical texts produced in the middle third of the seventeenth century. In the next section, I will examine the process and product of self-translation in the light of the same

[20] The translation is due to Fransen (2017b: 633, note 22).

research into sixteenth and seventeenth century self-translation, particularly as it relates to the works investigated in the case studies.

1.4.2 The process and product of self-translation

Many of the findings in self-translation research as they relate to the product and process of self-translation bring us back to the question posed above regarding the status of the self-translation as a rewriting of the original text. Two interconnected questions emerge from research findings. The second question involves second originals, as outlined in section 1.1 above. The first question is more complex, and concerns the degree to which self-translations are faithful to the original text. This is generally discussed in terms of the longstanding debate that evokes Marcus Tullius Cicero (106–43 BCE) and Horace (65–8 BCE), amongst others — and has been described by Jeremy Munday as dominating early translation theory — where literal, word-for-word (or ‘ad verbum’) translation is contrasted with free, sense-for-sense (or ‘ad sensum’) translation (2012: 29). The labels are inaccurate and unhelpful, however, as they set up an unnecessarily binary opposition between extreme approaches, whereas the majority of translators, including Cicero, who was cited by scholars between the fourteenth and seventeenth century as an advocate of the sense-for-sense approach (Robinson 2002: 7), use a full range of translation techniques, as appropriate to their needs.[21] They are nevertheless the terms in which much debate about translation strategy and methodology is conducted, including discussion of translation in France in the early seventeenth century, as will be seen in section 2.1.4, so I will continue to use them where appropriate.

Christopher Joby’s comment with regard to Huygens’s translation of a poem he wrote in 1619 — that Huygens ‘provides a translation that is more *ad sensum* than *ad verbum*’ — is typical of many of the conclusions drawn in research into Renaissance and Early Modern self-translation (2014: 208). Maria Langdale, meanwhile, believes that, in addition to *ad verbum* or *ad sensum*

[21] Michelle Bolduc notes, for example, that Cicero himself ‘translates literally at times, freely at others, and even invents new Latin terms’ (2020: 66). The characterisation of Cicero as an advocate of ‘free’ translation originates in a partial understanding of his practice, dominated by readings of his *De optimo genere oratorum* [On the Best Kind of Orators] (Bolduc 2020: 65). As Siobhán McElduff states, Cicero’s oft-quoted statement that ‘he translated “not as an interpreter but as an orator” [...] is only secondarily a statement about literal versus free translation’, and was primarily an answer to attacks on his oratory (2013: 5). His principal aim was to transfer oratory from Greek to Roman culture (Bolduc 2020: 57).

translations, Giannozzo Manetti (1396–1459) employed an approach to translating his *Dialogus consolatorius* [Consolatory Dialogue] (1438) that was 'freer' than either (1976: 3). In addition, di Teodoro notes that Barbero's Latin commentary on Vitruvius is 'un lavoro parallelo e con intersecazioni' [a parallel work with alterations] involving both additions and omissions (2012: 221). The sense-for-sense approach can also be seen in scientific self-translation: Miglietti finds, for example, that 'Mizauld's French versions are never literal translations of his Latin texts, but rather present themselves as a mixture of translation *ad sensum*, paraphrasis, and self-commentary' (2019: 223). The findings of all four scholars point to a general conclusion that Renaissance and Early Modern self-translation, like allographic translation in the same period, favoured adaptation to the host culture, usually for reasons of style.

The second important question regarding the finished product of self-translation is the status of the rewritten or self-translated version in relation to the original. Singer's description of his self-translations as second originals and Hokenson and Munson's notion of dual texts reflect the findings of scholars of Renaissance and Early Modern self-translation. Babbi, for example, notes that, like Singer, Calvin created a new, different work when he translated his *Christianæ religionis institutio* (1536): the title page of the *Institution de la religion chrétienne* (1541) stated that it had been 'reveue et augmentée' [revised and expanded] by its author (2011: 387). Langdale describes Manetti's *Dialogus consolatorius* and its vernacular self-translation, written on the death of his son, as 'two different works for two different classes of readers' (1976: 16). Langdale describes a 'livelier' vernacular text that includes 'precise vocabulary, idioms and metaphors which are far more felicitous than their Latin models' (1976: 4–5). Miglietti similarly describes what she refers to as Mizauld's deep transformation of his Latin texts on astrometeorology, where he removes scholarly paratext, 'makes liberal use of lexical amplification [and] adds elucidation, comparisons, and practical examples' (2019: 224). Marquant goes so far as to suggest that the Italian version of de Ortega's mathematical manual is so different that it appears to have been written from memory, '[c]omo si de un nuevo texto original se tratara' [as if it were a new original text] (2016: 339). He describes a number of techniques used by de Ortega, ranging from word-for-word translation to adaptation of geographically specific examples, along with the omission of an entire chapter on Spanish coinage that would have been irrelevant to the new Italian audience for his text (2016: 338). Each of these examples involves original works ‘translated’ or, more accurately, ‘transformed’ at a later date into very different texts, or ‘second originals’ through a process of consecutive self-translation. In all cases, distinguishing between the original version and the translation (or second original) proved fruitful; I will therefore adopt the same practice when discussing the case-study texts, particularly where consecutive self-translation is, or may be, involved.

The notions of dual texts and simultaneous self-translation are particularly helpful when it is impossible to decide which of the texts is the original or when the two texts are written at the same time. Joby describes Huygens’ self-translations in this way: he sees Huygens’ work less as translation and more as ‘parallel creative acts, where a common theme [...] is determinative rather than a source text’ (2014: 205). The concepts of dual texts can also be useful even when the order of composition is clear. In his investigation into Bodin’s self-translation of political texts, Turchetti found that analysis of differences between the two texts was invaluable in tracing the development of Bodin’s thought. In addition, he found that ‘the two texts often complement each other, because of the added clarity brought to many passages by Bodin’s fuller exposition in Latin of points made more briefly or ambiguously in French’ (2012: 111). I will explore this idea of complementary dual texts in chapter 4 on Mersenne’s *Harmonie universelle* and *Harmonicorum libri*.

All of the scholars whose work has been mentioned in this section have revealed valuable insights into the process of self-translation: it is clearly a rewriting process, and occasionally simply a writing process, that produces two texts. One text may be an original from which the second version is derived by translation, but equally the texts may be dual versions where the notion of original and translation no longer apply. In most cases, the order in which the two texts are created is evident, but on occasion either this clarity is lacking, or the works are created simultaneously, thereby blurring the distinction between original and translation, or first and second original.

1.5 Chapter conclusion: implications for the research

The purpose of this research study is to present three pairs of mathematical texts from the 1630s and 1650s as case studies in self-translation. The aim in the case studies will be to focus on the issues and questions raised in this chapter and draw a range of specific conclusions about the separate pairs of works as well as general conclusions common to all three. The principal questions to be answered will involve examination of the works' authors' motivations for creating them as self-translations and their practice in doing so. In order to answer these questions, it will be necessary to examine the bilingual works at both the micro and macro levels advocated by Hokenson and outlined above.

At the micro, cultural and personal level, I will investigate any individual factors that may have led the self-translating authors to write their texts as bilingual works. At this stage it will be helpful, as Grutman has suggested, to examine the self-translations in the context of any other self-translations the mathematicians carried out, investigating the direction of any translations, their frequency and the point at which they occurred in their authors' careers, and to examine the time gap between the two versions of the self-translations to see whether they were composed simultaneously, near-simultaneously or consecutively (2009a: 257). These more personal, micro-level factors will be investigated in chapters 3, 4 and 5, where the self-translations will be studied in depth. With respect to the finished products, it will also be particularly fruitful to examine the degree of overlap and difference between the two versions of each text, as suggested by Hokenson and Munson (2007: 4). This examination will include an investigation at the level of structure, content, language use and rhetorical style. This will enable me to determine the extent to which the second version can be said to constitute a second original (Grutman and Van Bolderen 2014: 324) and whether the versions constitute dual texts (Hokenson and Munson 2007: 11). In this context, it will also be interesting to see how the two versions complement each other and whether there is any evidence that the process of self-translation led to revisions in the original, and to determine the extent to which either version could be said to have overshadowed the other (Santoyo 2013a: 34).

Before examining separately the micro-level reasons for writing the pairs of texts as self-translations and investigating them in detail from a number of perspectives, in the next chapter I will begin at the macro level and examine the most significant social and historical forces at play in France in the middle third of the seventeenth century that influenced the writing of the three mathematical self-translations. Appreciation of these factors is essential for understanding the context in which all three case-study authors were working. Consequently, they have been placed together in a single chapter to avoid repetition across the three case studies. The macro-level factors can be divided into linguistic and mathematical forces that influenced the production of the bilingual works and audience-related considerations that had an impact on the reception, or, more accurately, the potential reception, of the works.

Chapter 2

The seventeenth-century context

The purpose of this chapter is to act as a reference chapter: it contains descriptions of the most significant social and historical factors that influenced the composition of the three mathematical works being investigated in this thesis. All of the topics covered in this chapter relate to at least two of the case studies and will therefore contribute to a greater understanding of them and obviate the need to repeat the same background information in more than one chapter. The factors I will examine in this chapter relate both to the scholars' motivation for writing the texts as bilingual works and to the decisions they made when composing them (the 'why' and the 'how'). The social and historical factors can be divided into three general types: linguistic, mathematical, and audience-related. It should, however, be noted that some of the factors belong to more than one type; where this is the case, they will be described under the most relevant heading.

Section 2.1 will begin with an outline of the changing relationship between Latin and French in the sixteenth and seventeenth centuries, before going on to examine the relationship between the two languages in seventeenth-century printing, particularly of mathematical texts, and finishing with discussion of approaches to translation in France in the first half of the seventeenth century. This will be followed in section 2.2 by consideration of the historical processes that informed the mathematics of the sixteenth and seventeenth centuries, particularly the impact of successive translation programmes on the dissemination of mathematical knowledge, and also the development of mathematical terminology, symbols and signs, and modes of proof and persuasion. The chapter will finish, in section 2.3, with a study of two major historical factors that created audiences for the Latin and French mathematical works: the French educational system and the Republic of Letters.

2.1 The emergence of French and its relationship with Latin

For centuries in southern Europe, including the area now covered by France, Latin and the vernaculars coexisted in states of diglossia (Ferguson

1959: 337) and even polyglossia (Gutbub 2015: 183).[22] In France and the territories where the Romance languages are now spoken, a range of vernacular languages were used in ordinary conversation throughout this period, but Latin was the prestige language, the language of the elite, the Church and the education system (Ferguson 1959: 337). If languages continue to be compartmentalised into different functions in this way, then the stability required for diglossia to persist is also maintained (Wei 2007b: 27). This situation can last for several centuries, as in the case of Latin and the emerging French language (Lodge 1993: 14, 119–20). Once the two languages begin to compete for use in the same societal contexts, as happened in all of the Romance-speaking territories, a process begins where one of the languages is eventually abandoned by the speech community (Wei 2007b: 27–28). The conditions for the disruption of diglossia include more widespread literacy, improvements in communication, and the desire for a standard national language as a marker of national sovereignty (Ferguson 1959: 338). In France, all of these conditions emerged gradually so that, by the seventeenth century, diglossia in France had effectively ended, although it took a long time for Latin to disappear from use: many scholars, including the case-study mathematicians, worked bilingually during this period. While diglossia in the Romance-speaking countries was undoubtedly undermined by the factors mentioned above, the vernaculars did not suddenly simply replace Latin. As Jan Bloemendal has pointed out, recent research shows that Latin and the vernaculars ‘coexisted together for centuries in overlapping and mutually influential communities’ (2015b: 2). Moreover, the relationship between Latin and the vernacular languages changed over time, at different periods and over different timescales for the various vernaculars (Bloemendal 2015b: 5).

[22] The term ‘diglossia’ ‘describes the functional differentiation of languages in bilingual and multilingual communities’ (Wei 2007b: 27). It was first coined by Charles Ferguson in the article cited to describe ‘speech communities [where] two or more varieties of the same language are used by some speakers under different conditions’ (1959: 325). In diglossia, co-existing languages in a community are likely to be used in different contexts for different functions (Wei 2007b: 27). Typically, one of the languages, known as the High (or H) language, is used in formal situations such as religion, education, administration, the law, and literature and has higher status than the other, Low (or L) language, which is used in more informal situations, such as daily conversation, instructions to servants, and folk literature (Lodge 1993: 13–14). The H language is universally considered to be superior to the L language (Ferguson 1959: 329–30). However, no-one in the speech community regularly uses H for daily conversation (Ferguson 1959: 336–37). John Platt uses the term ‘polyglossia’ as an extension of ‘diglossia’ to describe the use of more than two languages in different functional situations (1977: 361–62); it is this extension of the term that Christophe Gutbub uses in relation to mediaeval France (2015: 183). All references to diglossia in this thesis should be considered to be relevant to situations where polyglossia also exists.

2.1.1 Latin and French in the sixteenth and seventeenth centuries

As Anthony Lodge has noted, the diglossic situation in France changed gradually between the thirteenth and sixteenth centuries as what would become French progressively grew in prestige, acquiring a wide range of official and public functions (1993: 120, 149). During this period, this patois began to gain greater status than other local dialects. By the twelfth century, there were a number of prestigious regional varieties of the Romance languages that had succeeded Latin in what is now France, their prestige based on regional centres of power and wealth (Lodge 1993: 98). By the end of the twelfth century, however, the variety used at the King's court in Paris had begun to be viewed as the dominant northern vernacular (Lodge 1993: 98). The expansion of the power of the kings based in Paris over the course of the following four centuries meant that, by the middle of the sixteenth century, French had become the language of administration for the whole country.

The relationships between Latin and French and between French and the regional vernaculars continued to change throughout the sixteenth century, with French gradually gaining prestige. In the first half of the sixteenth century, Latin was still the dominant language of education, learned culture and the learned professions (White 2015: 411). French was not considered capable of becoming a language of science, at this stage: humanist efforts to advance the case of French in the sciences did not begin until the 1550s (Pantin 2000: 41). A key moment in establishing the prestige of French occurred in 1539, when François I passed the Ordinance of Villers–Cotterêts, whereby French would replace Latin and the other vernaculars of France as the language of law and administration (Lodge 1993: 126–27). At around the same time, a number of other events solidified the status of French as the dominant vernacular language and demonstrated that it had begun to be considered as a language with equal status to Latin and worthy of study (Lodge 1993: 131–32). A royal print was established in 1543 to promote the use of French (Brunot 1922: 27). There were increasing numbers of translations of texts from Latin: successful translations demonstrated that French could express ideas that had previously been confined to Latin (Rickard 1974: 102). The publication in 1549 of du Bellay's *Deffence et illustration de la langue françoyse* [Defence and Illustration of the French Language] marked the moment when French was first considered as worthy of study in its own right (Lodge 1993: 132). In addition, initiatives such as that undertaken by Estienne Pasquier (1529–1615) to draw up a French literary canon in his *Recherches de la France* [Researching France] (1560–1621), set out to establish French as the nation's sole language (Chenoweth 2016: 375). Although French did not immediately replace the numerous other regional patois in everyday use (Chenoweth 2016: 379), language dynamics had altered significantly since the Middle Ages: French was on its way to becoming established as the national language (Leonhardt 2013: 193).

Despite the progress being made by French in a number of areas in the sixteenth century, Latin was still the dominant scholarly language. Few of the Renaissance humanists actually wrote solely in French (Rickard 1968: 2). This was even true of the poets of the *Pléiade*, who wrote in both French and Latin, including du Bellay, who was a prominent member (Leonhardt 2013: 194). Latin was also still the language of education and the Church (Casanova 2008: 95). Increasingly in the sixteenth century, however, arguments were made in favour of teaching in French in the colleges and universities (Rickard 1968: 5). By the end of the century, Latin was becoming marginalised as the unchanging language of the universities and the Church (Lodge 1993: 132). Paradoxically, this marginalisation was accelerated by the humanists' revival of interest during the Renaissance in Latin and Greek and in Europe's Graeco-Roman heritage (Deneire 2014b: 2).

The increased interest in Latin and Greek had two seemingly contradictory outcomes: on the one hand, the desire for national languages grew, while, on the other, Latin (or more accurately, neo-Latin) became the continent's *lingua franca* (Deneire 2014b: 2). The enthusiasm of humanists across Europe for spreading the ideas of Antiquity beyond a Latin-educated elite meant making them available in languages people understood (Deneire 2014b: 2). Like other sixteenth-century vernacularisers, Mizauld argued that not translating Latin works into French excluded the majority of the population from access to valuable knowledge (Miglietti 2019: 223). The growth in printing increased the potential audience for books in the vernacular languages (Sanson 2013: 240; Lodge 1993: 128). In France, as literacy increased from the sixteenth century, writing in French also helped spread the standard version of the language (Lodge 1993: 166). While standard French was expanding its reach, the Renaissance mission of 'purifying' Latin had made it less suitable as a language to deal with contemporary needs (Rickard 1974: 90; Sanson 2013: 239). The outcome was that Latin's monopoly as the language of written culture was being undermined (Lodge 1993: 130). By the beginning of the seventeenth century, the relationship between Latin and French had changed further: in common with Spanish, Italian and English, French had displaced Latin outside the Church, the schools and the universities (Leonhardt 2013: 193). Latin was also no longer the dominant language of literature (White 2015: 421). Diglossia (and polyglossia) had effectively ended, to be replaced by the bilingualism (and multilingualism) of the seventeenth century.

At the same time as it began to lose its pre-eminent position in the emerging nation states, Latin began to redefine itself (Ramminger 2016: 4). Peter Burke has characterised its status in the sixteenth and seventeenth centuries as 'a language in search of a community' (2004: 44). It was 'the only truly international language — spoken, written, and read all over Europe and beyond' (Knight and Tilg 2015b: 3). In this role as a *lingua franca*, Latin gave cohesion to the Republic of Letters (Burke 2004: 44). It had become a versatile language that allowed scholars to communicate across political and linguistic borders (Ramminger 2016: 7). It was for this reason that, in 1640, Mersenne wrote to German Calvinist scholar Theodore Haak (1605–1690) saying that he hoped for an academy to be created where men of learning would translate the best works in each language into Latin, 'la langue commune de l'Europe chrétienne' [the common tongue of Christian Europe] (1970: 420). The positive view of Latin as the universal language of European scholarly communication was not shared by all: the educational reformer John Amos Comenius (Jan Ámos Komenský, 1592–1670) bemoaned its complexity and frequent ambiguity, while a number of seventeenth-century creators of philosophical languages criticised its lack of a rational, logical character (Waquet 2001: 258). By the eighteenth century, French had begun to take the place of Latin as the language of communication and diplomacy across Europe (Chevrel et al 2014b: 48; Rickard 1974: 121). Nevertheless, Latin still had its adherents as the primary language of the Republic of Letters: in 1765, Nicolas Beauzée (1717–1789) wrote in the *Encyclopédie* of Denis Diderot and Jean le Rond d'Alembert that '[l]a langue latine est d'une nécessité indispensable, c'est [...] la langue commune de tous les savans de l'Europe' [Latin is an absolute necessity, it is (...) the common language of all the scholars of Europe] (Beauzée 1765: 265; Leca-Tsiomis 2010: 180).

It is clear from this account of language dynamics in France that, by the seventeenth century, French had increased its reach in France so that it was now considered capable of being a scholarly language with the potential to replace Latin in that role, while Latin's role was being solidified as the *lingua franca* of the Republic of Letters. Although both languages would go on to assume these roles, the relationship between them was far from clear-cut at this stage, and was still in a state of flux. This was certainly the case for the publishing of science and mathematics texts, as the next two sections will demonstrate.

2.1.2 Latin and French in publishing

For the purposes of this investigation, the most significant features of printing and publishing in the first two-thirds of the century are the numbers of mathematics texts written and published, and the comparative proportions of those books written and published in the two languages. Henri-Jean Martin has analysed the seventeenth-century French and Parisian book trades in detail (1969 and 1982). He has discovered that data for book production up to 1650 is incomplete and can only be extrapolated from available sources (1982: 443). Nevertheless, it is clear that the majority of books published in France during this period were printed in Paris, particularly new books (Martin 1982: 442–43); this includes the three books being investigated in this thesis. The number of books published annually in the city rose from between 300 and 450 at the beginning of the century to close to a thousand by 1644 (Martin 1982: 443). In 1644, Martin also estimates the average print run to be between 1000 and 1500 copies (1969: I, 378; 1982: 443).[23] After the 1640s, book production fell back during a period of unrest and recession, before recovering in the 1660s and

[23] Martin quotes Gabriel Naudé (1600–1653), 'considered the first important theoretician of modern library organization' (The Editors of Encyclopaedia Britannica 2021), as suggesting that the usual print run for works of mathematics would be 500 copies, and never more than 750 (1969: I, 378, note 64). Similarly, Isabelle Pantin suggests that a print run for a scholarly text in the sixteenth and seventeenth centuries would have been approximately 600 copies (2007: 164). In the absence of reliable data, the figure of 500–750 copies is therefore likely to be a reasonable estimate for the number of the case-study texts that were printed.

maintaining its level of production for the rest of the century (Martin 1969: II, 598, 1062).

The proportion of books that Martin categorises variously as ‘sciences et arts’ and ‘sciences et techniques’ remained reasonably steady at between 10% and 20% per year throughout the seventeenth century (1969: II, 1065). This equates to an annual output of fewer than a hundred books for all science subjects in the first half of the century. As this data covers a large range of scientific subjects and a significant proportion of this output dealt with medicine, it can be seen that there were likely to be very few books published on any other individual scientific subject in any given year (Martin 1982: 446–49). The implications for mathematics can be seen in appendix 1 and will be dealt with in section 2.1.3 below.

Martin has also investigated the relative proportions of books published in Latin and French. He estimates that, in France as a whole, publication of books in French overtook those published in Latin in about 1560 (1982: 445). Martin and Lucien Febvre have discovered that the book-reading public had become increasingly lay and non-academic, made up of more and more people with very little knowledge of Latin (Febvre and Martin 1976: 320). The balance in publishing altered rapidly: in the first half of the seventeenth century, the proportion of books published annually in Latin remained steady at around 20% (Martin 1969: II, 1064 and 1982: 448–49). Further changes in French society meant that there was less demand for books in Latin in the second half of the century, falling to less than 10% by the late 1660s, a figure that remained constant until the end of the century (Martin 1969: II, 598, 1064). In a survey of a control group of six hundred authors, David Pottinger found that the proportion of books published in Latin stood at 30–40% in the early seventeenth century but below 10% in 1700 (1958: 18). Although the two scholars’ findings disagree on the exact proportion of books published in Latin, their overall conclusion is the same: the use of Latin in publishing in France declined during the seventeenth century to the point where only approximately one book in ten was published in what had been the dominant language of publishing up to the middle of the sixteenth century. Martin’s interpretation of what he refers to as ‘l’abandon du latin’ [the abandonment of Latin] in the second half of the seventeenth century is that the first half of the century saw the end of the humanist desire for classical erudition and gave way to the classical period in French letters characterised by a focus on the clarity and beauty of the national language (1969: II, 598).

2.1.3 Latin and French in mathematical texts

The end of the emphasis on classical learning that characterised the Renaissance and the increased promotion of, and confidence in, French as a national language capable of representing learning and scholarship of all kinds were the strongest trends signalling the changed relationship between Latin and French. It was inevitable that this changing relationship would be reflected in the publishing industry at the same time that it was visible elsewhere in society. It is therefore not surprising that the period when Latin was losing its status across Europe and was being redefined as the language of scholarly Europe was a critical period for its use in science and mathematics. According to Fransen, 'the first half of the seventeenth century in Western Europe [was] the period in which Latin gradually lost its status as the preeminent language of scientific discourse and ceded ground to the European vernaculars' (2017b: 629). Blair argues that the tipping point in France, as elsewhere in Europe, came in the 1630s and 1640s, as part of a movement away from traditional science, the universities that stood at its centre, and Latin, the language of both (2000: 27). It was during this period – in 1636 – that Latin was first recorded as being referred to as a 'langue morte' [dead language] in France, though this view of the language did not become common until the eighteenth century (Colombat 1992: 32). This was also the period in which Hérigone published the *Cursus mathematicus* and *Cours mathématique* (1634–42) and Mersenne the *Harmonicorum libri* and *Harmonie universelle* (1636–37), and the period just before Pascal wrote the treatises on the Arithmetic Triangle (1654); there is no evidence that any of them saw Latin in a negative light.

The first half of the seventeenth century was not the first time that works of science and mathematics had been written in French: works of applied science, particularly those dealing with remedies, surgery and practical astrology, had first appeared in the thirteenth century (Blair 2000: 19). French was also used in practical arithmetic books from an early date: it was the obvious choice of language as these practical works were primarily intended for a French-speaking rather than a Latin-speaking audience (Blair 2000: 22). This trend in vernacular printing was not confined to France, but occurred across Western Europe (Cohen 2015: 146). Scholarly writing about science and mathematics was generally undertaken in Latin throughout Europe but, in the sixteenth century, the vernacular began to be used for some of this more abstract work, especially if it did not come directly from classical sources (Cohen 2015: 147–48). Highly abstract geometry and natural philosophy mostly remained in Latin, while empirical research was in Latin and the vernaculars in equal measure (Cohen 2015: 148). The general European situation was reflected in France: theoretical mathematics and science largely remained in Latin. The situation began to alter in the second half of the sixteenth century, when Peletier, Pierre Forcadel (1550–1572) and other scholars wrote original works in French to show that French could be used as a vehicle of science (Rickard 1968: 5; Pantin 2000: 41). Peletier, for example, instigated a programme for promoting French as the language of science, particularly algebra, in the 1550s and 1560s (Cifoletti 2000: 91–92).

Wholesale adoption of French was slow, however. The ease with which established Latin terminology was understood, coupled with the desire to communicate beyond France, meant motivation to use the vernacular was not always high (Febvre and Martin 1976: 329). Furthermore, Latin continued as the primary language in the education system; Peletier even translated his own algebraic work into Latin so that it could be used at the Collège Royal (Cifoletti 2000: 99–100). The second half of the sixteenth century was also a period when, as will be seen in section 2.2.1 below, large numbers of theoretical mathematical texts were translated into neo-Latin from Greek as part of the humanist project, mainly in Italy (Pantin 2000: 42; Ogilvie 2015: 267). These translations acted as catalysts for mathematical innovation which was often also written in neo-Latin (Pantin 2000: 42–43). At this stage, use of the vernacular was still generally frowned upon (Febvre and Martin 1976: 329–30). Consequently, translations into French of the Latin translations of the ancient Greek works or new mathematics written in Latin, such as the algebraic work of François Viète (1540–1603), were generally not made until the late sixteenth and early seventeenth centuries.

By the end of the sixteenth century, French had begun to rival Latin as the language of scholarship but had not yet fully displaced it (Lodge 1993: 128). Nevertheless, within a few years, the situation had changed: Blair suggests that '[l]a petite vague de vernacularisation de la philosophie naturelle à la fin du XVIe siècle devient raz-de-marée au début du XVIIe siècle' [the small wave of vernacularisation in natural philosophy at the end of the sixteenth century became a tidal wave at the beginning of the seventeenth] (2000: 37). The early seventeenth-century scholars were well read in Latin and so were able to choose the language in which they wrote (De Smet 2014: 1073). In fact, many scholars throughout the entire Early Modern period were bilingual, and some were multilingual (Bloemendal 2015b: 6). Fransen has noted that, in the first half of the seventeenth century, '[a]uthors of scientific texts exhibited a high level of awareness about their choice of language' (2017b: 629). Of the principal scholars writing mathematical texts in the period 1610–1665, the French mathematician and astronomer Pierre Gassendi (1592–1655) wrote mainly in Latin while many, including Mersenne, wrote in both French and Latin (White 2015: 421). Descartes also switched between Latin and French, and is said by his biographer to have found writing about mathematics easier in Latin than in French (Waquet 2001: 89). Pascal wrote mostly, but not exclusively, in French, as will be seen in chapter 5. The languages used by these and other, less well-known scholars can be seen in the tables of mathematical texts in appendix 1.[24]

The corpus of mathematical texts I have compiled in appendix 1 shows that, while French may eventually have superseded Latin as the language of scientific and mathematical texts, the situation in the early and middle years of the seventeenth century with regard to scholarly mathematical texts was far from clear-cut. The corpus shows that, during the period between 1610 and 1665, slightly more mathematical works were written in French than in Latin (60 of 111, or approximately 54%, in French and 51, or 46%, in Latin). In apparent contradiction of the general trend in French scientific publishing, a greater number of books were published in French than in Latin in the first part of this period (1610–1639), while the opposite was true for the later part (1640–1665). This outcome might well be the result of a relatively small corpus (an average of

[24] Appendix 1 contains a corpus of 111 major mathematical works written between 1610 and 1665 that I have compiled for this investigation. It includes a list of the mathematical works written by the most renowned French mathematicians active at some stage in that period and my rationales for choosing the dates, the mathematicians and their works.

approximately two books per year over the entire period), so that individual scholars with a comparatively large output skew the data.[25] Françoise Waquet detects other potential reasons: the persistence of Latin as the language of learned Europe, including the universities, and the fact that many scholars found that they read and wrote more fluently in Latin than in French (2001: 87–89). In addition, she found that 'the vernacular did nothing at all to increase the circulation of these writings' (2001: 90).

Other potential factors that may have influenced the mathematicians' choice of language include their personal circumstances (their family and educational backgrounds and their positions in society in particular) and the subject matter of their works. The majority of the authors whose works are listed in appendix 1 came from wealthy backgrounds, many from noble families, including Claude-Gaspar Bachet de Méziriac (1581–1638), and were highly educated, either at home, like Pascal, at a high-prestige college, like Descartes, or at university, like Jean-Baptiste Morin (Schaaf 1981a: 367; Rogers 2003: 5; O'Connor and Robertson 2014, 1997). A small number, including Hérigone, Gilles Personne de Roberval (1602–1675), Honoré Fabri (1607–1688), and Morin (1583–1656), were professors or teachers of mathematics (Strømholm 1981: 299; Hara 1981b: 486; Fellmann 1981: 505; Costabel 1981b: 527). In all cases, a strong knowledge of Latin can be assumed. A small number of the mathematicians came from more humble backgrounds, including Abraham Bosse (1602–1676), Mersenne and Roberval (Taton 1981a: 333; Crombie 1981: 316; Hara 1981b: 486), while little is known about the early lives of Henrion, Hérigone and Jean Leurechon (*c.* 1591–1670) (Itard 1981: 271; Strømholm 1981: 299; Schaaf 1981b: 271). Amongst this group, Mersenne is known to have received his education at the prestigious Jesuit college of La Flèche, and Roberval was largely self-educated, while little or nothing is known about the education of the remaining men (Crombie 1981: 316; Hara 1981b: 486). This small group includes two mathematicians – Henrion and Bosse - who wrote their works almost exclusively in French (Itard 1981: 271–72; Taton 1981a: 333–34), but more – Mersenne, Hérigone, Roberval and Leurechon – who composed a number of works in both languages (Hara 1981b: 487, 490; Schaaf 1981b: 271–72). It can therefore be concluded that, in general, the men

[25] In the early part of the period, for example, Denis (or Didier) Henrion (*c.* 1580–*c.* 1632) is responsible for eleven works, most of which were practical in nature and all written in French; without his contribution, the numbers of books in the two languages would be approximately equal.

who produced mathematical works in the period 1610–1665 were proficient in both Latin and French as a result of their educational background, whether as students or teachers, and so were able to choose between the two languages. A lack of detailed knowledge about some of the mathematicians makes it more difficult to come to more specific conclusions.

In many cases, including those of Henrion and Bosse, it was more likely to be the subject matter, and the intended readership for that subject matter, that determined the choice of language and explains the preponderance of books in one language in a particular period (Waquet 2001: 90). In the first half of the period, there were four notable trends. The first was the publication of recreational mathematical books, four of which were published between 1612 and 1630, all in French. These included Bachet de Méziriac's *Problemes plaisans et delectables, qui se font par les nombres* [Pleasant and Delightful Problems Made by Numbers] (1612), described by Michel Ballard as 'un recueil de "divertissements" pour amateurs éclairés' [a collection of "amusements" for enlightened amateurs] (1998: xiii).[26] The second trend involved collections of the Latin translations of the classical mathematical texts of ancient Greece (Martin 1969: I, 244). Among the first were Leurechon's *Selectæ propositiones in tota sparsim mathematica pulcherrimæ* [Most Beautiful Propositions Selected from Various Places in Mathematics] (1622), and Mersenne's *Synopsis mathematica* [Mathematical Synopsis] (1626), which was edited for republication as the *Universæ geometriæ synopsis* [Universal Synopsis of Geometry] (1644) (Martin 1969: I, 244). Leurechon's work was 'a collection of propositions in mixed mathematics that were used for teaching' (Rittaud and Heeffer 2014: 28). The audience for Mersenne's work, on the other hand, was most likely the mathematicians in his circle and across Europe (Martin 1969: I, 244–45). The purpose for collecting these works was not to preserve them, but to learn from them and use them to spread mathematical knowledge and create new, innovative work (Eisenstein 1979: I, 291). Much of the innovative mathematical work in Europe originated with members of Mersenne's academy and his wider group of contacts, as will be seen in chapter 4. As well as Latin collections, mathematical compilations in the vernacular aimed at non-academic readers also began to attract interest in mathematics from the 1630s onwards.

[26] So influential was Bachet de Méziriac's work that '[a]ll subsequent puzzle books are indebted to it, and it has kept its relevance for centuries, republished most recently in 1959' (Bellos 2020: 237).

Hérigone's bilingual *Cursus mathematicus* and *Cours mathématique* was a very comprehensive example of this type of publication (Martin 1969: I, 250). The intended audience for Hérigone's work was wider than that for Mersenne's work: it included both experts of the type found in Mersenne's academy and the Republic of Letters, as well as non-expert mathematicians, as will be seen in chapter 3.

The third trend discernible in the early part of the period covered by appendix 1 was for practical books demonstrating the use of mathematical instruments. Six of the books in the corpus are of this type of work, all of which were published in French between 1618 and 1647. Typical of the genre was *L'usage ou le moyen de pratiquer par une règle toutes les operations du compas de proportion* [The Use or Means of Practising with a Rule all of the Operations of the Proportional Compass] (1634) by Pierre Petit (1594/1598–1677). The final trend is less obvious in appendix 1, but is described by Martin: single-sheet 'placards', or posters, stuck up to announce mathematical challenges or provide solutions to mathematical problems (1969: I, 245). Most were ephemeral by their very nature, but the best-known example, Pascal's *Essai pour les coniques* [Essay on Conics] (1640) is included in appendix 1.

Other trends are identifiable across the whole period surveyed. For example, works on music and architecture were also almost all written in French, although any conclusions about the choice of language would need to take into account the fact that most of the books on the former topic and all on the latter were written by a single author in each case (Mersenne and Bosse respectively), thereby again skewing the results. Books that were mostly written in Latin across the full 56-year period include works on astronomy (eleven in Latin and two in French) and, to a lesser extent, geometry (fifteen in Latin, thirteen in French). It is likely that these areas of study were considered particularly abstract and therefore of more interest to an intellectual European audience than the vernacular audience targeted by the practical and recreational books mentioned above. More books were written on geometrical topics than any other (28 of 111, i.e. over a quarter of all mathematical books) and the proportion of books on geometry within the Latin corpus was higher than in French (15 of 51 Latin books, or 30%, compared to 13 of 60 in French, or just over 20%). Geometry had been the traditional focus of mathematicians since Antiquity and still held that position in seventeenth-century France, so it was more often published in the classical language. It is, however, notable that most geometry books written early in the period, particularly in the 1630s, were written in French, while the majority written later, particularly in the 1650s, were composed in Latin.[27]

For the purposes of this thesis, it is also significant that eighteen of the 111 works listed in appendix 1 form nine pairs of bilingual texts, accounting for 16% of the books in the corpus.[28] Eight of the pairs of bilingual works were written in Latin and French and the other in Dutch (with a Latin title) and French. Two of the pairs of bilingual works are practical books containing logarithmic and trigonometric tables and short treatises on how to use the tables in calculations. Two of the remaining seven works involve a Europe-wide competition (Pascal's accounts of a contest to solve problems involving the cycloid, which will be discussed briefly in chapter 5). Of the five remaining pairs of books, Leurechon's *Brevis tractatus de cometa viso mensibus novembri et decembri anno elapso* [Brief Treatise on the Comet Seen in November and December Last Year] and *Discours sur les observations de la comete de 1618* [Discourse on the Observations of the Comet of 1618] (both 1619) concern astronomy, and *La Perspective curieuse, ou, Magie artificielle des effets merveilleux* [Curious Perspective, or Artificial Magic of Marvellous Effects] (1638) and *Thaumaturgus opticus, seu admiranda* [Optical Wonder, or Marvels] (1646) by Jean-François Niceron (1613–1646) deal with perspective. The remaining three are the works I have chosen to investigate in this thesis; the reasons for selecting the three works in question were provided in the introduction and will be revisited throughout the rest of the thesis.

It should be noted that, although seventeenth-century mathematicians felt able to choose between French and Latin in their writing, or to compose in both languages, this did not lead to the immediate abandonment of Latin (Rickard 1974: 90). Scientific and mathematical works continued to be composed in Latin throughout the rest of the century. Moreover, as noted above, whereas in the sixteenth century and very early seventeenth centuries it had become common to write texts in Latin and translate them into French for a

---

[27] Of the nine books on geometrical topics in the corpus written in the 1630s, seven were written in French; in the 1650s, eight of eleven geometry books were composed in Latin.
[28] See appendix 1, section B, for the full list of bilingual works.

newly educated French audience, in the seventeenth century texts were often written in the vernacular and translated for dissemination around Europe, or written simultaneously for both audiences. Mersenne's case-study works exemplify the latter tendency and Descartes's *La Géométrie* [Geometry] (1637) is a prime example of the former. Sales of Descartes's work were disappointing until it was translated into Latin, at which point interest increased considerably and the work became much better known (Blair 2014a: 957). In addition, it was the Latin text that became the standard version of the book, with added appendices and commentaries (Pantin 2007: 170–71). In fact, significant numbers of science texts of various types were still being written in Latin throughout the eighteenth century (Waquet 2001: 88). Descartes's experience with *La Géométrie* and *Geometria* provides an illustration of the important role translation plays in disseminating mathematical knowledge between cultures. Also significant were the strategies that translators adopted to translate their texts: approaches to translation in France were constantly changing in the seventeenth century, as the next section will demonstrate.

2.1.4 Translation: theory and practice

In the early years of the seventeenth century, Latin was still the most common language from which translations were made (Chevrel et al 2014b: 34), and most of the works translated were from Antiquity (Juratic 2014: 192). Debates about translation in the early years of the century reflected what Yen-Maï Tran-Gervat and Frédéric Weinmann describe as 'une hésitation entre deux positions en apparence inconciliables: le respect du texte traduit et l'attention à la langue d'arrivée [uncertainty between two apparently irreconcilable positions: respect for the text being translated and concern for the target language] (2014: 252). The first three decades of the century were characterised by attempts to balance 'free', or sense-for-sense, translation with 'faithful', or word-for-word, translation (Tran-Gervat and Weinmann 2014: 253–56).[29] The poet and translator François de Malherbe (1555–1628), for example, recommended in his *Histoire romane* (1621) that the translator should take the middle path between overly strict word-for-word and overly free translation, making only necessary

[29] Tran-Gervat notes that 'traduction libre' [free translation] and 'traduction mot à mot' [word-for-word translation] were the most commonly used terms for the alternative approaches to translation in the early seventeenth century (2014: 379–80); free and word-for-word translation are therefore the terms that I will use in discussing approaches to translation during this period.

alterations to clarify a text without altering its meaning (Tran-Gervat and Weinmann 2014: 258). However, pride in the French language meant that adhering too closely to the source text was beginning to be seen as too restrictive (Tran-Gervat and Weinmann 2014: 256).

The 1630s and 1640s, when Hérigone and Mersenne produced their bilingual works, saw increasing consideration of the French language and the target audience and a consequent move away from the middle path advocated by Malherbe towards 'freer' translation, despite the efforts of Bachet de Méziriac, who, in his *De la traduction* [On Translation] (1635), which was read out in one of the first addresses to the *Académie française*, pleaded for fidelity to both the words and meaning of the source text (Tran-Gervat and Weinmann 2014: 259). Julie Candler Hayes and Roger Zuber both find that the principal concern of allographic translators of literary and historical texts from Latin during these decades was to provide clarity and render the beauty and sense of the original, while imitating its eloquence, in order to provide a model for French (Hayes 2009: 29–32; Zuber 1968: 50–51). Antoine Godeau (1605–1672) was an early advocate of this approach: in his preface to the 1630 translation by Louis Giry (1596–1665) of the *Des Causes de la corruption de l'éloquence* [On the Causes of Corrupt Eloquence] by Publius Cornelius Tacitus (56–*c.* 120 CE), for example, Godeau praises Giry's clarity of translation in the following terms: 'Sçachant que ce n'est pas bien traduire, que de rendre mot pour mot, [...] il a [...] adjousté quelquefois une ligne pour expliquer ce qui pouvoit estre obscur' [In the knowledge that translating word for word is not a good translation method, (...) he has (...) sometimes adjusted a line to explain what would otherwise have been unclear] (1630: xi). As well as advocating avoidance of word-for-word translation, Godeau also praised fidelity to the sense of the original as the prime goal of the translator, invoking classical translators as exemplars (Tran-Gervat and Weinmann 2014: 260). He also praised his sixteenth-century predecessor, Jacques Amyot (1513–1593), whose approach to translation was to replicate an author's style while also attempting to translate a work as faithfully as possible (Ballard 2007: 121).

The main proponent of the new approach to translation in the 1630s and 1640s was Nicolas Perrot d'Ablancourt (1606–1664), one of the translators tasked by Valentin Conrart (1603–1675), the founder of the *Académie* *française*, with translating a range of classical texts.[30] In commenting on d'Ablancourt's approach in translating the *Octavius* (1637) of Marcus Minucius Felix (died *c.* 250 CE), Hayes states that he 'does not seek to render word for word, or even necessarily sense for sense; rather, he hopes to capture the aesthetic and affective power of speech' (2009: 31). For d'Ablancourt, fidelity in translation meant fidelity to the author's intentions and to the audience's enjoyment, not to the words of the text, which he believed should only be the preserve of biblical translators or grammarians, with the result that he created a 'second original' (Tran-Gervat and Weinmann 2014: 261–62). D'Ablancourt characterised his approach as 'traduction libre' in a commentary on his translation, *Lucien* (1654), of the works of Lucian of Samasota (*c.* 125–after 180 CE) (Tran-Gervat 2014: 380). In his practice, d'Ablancourt was followed by other translators who sought to embellish their translations, rewriting texts for a contemporary audience (Ballard 2007: 172; Nama 1995: 40–41). By the late 1640s, the years directly preceding Pascal's composition of his treatises on the Arithmetic Triangle, resistance to the free translation practised by d'Ablancourt and his fellow translators had become evident, particularly amongst the translators based at the Abbey at Port-Royal. Even amongst these scholars, however, there were disagreements between those who advocated fidelity to the source text and those who preferred to take a middle way similar to that advocated by Malherbe earlier in the century (Tran-Gervat and Weinmann 2014: 262–64).

The debates in literary and historical translation in the first half of the seventeenth century were reflected in translation of scientific works in all disciplines, though the concerns of the scientific translators differed from those of their literary peers: the principal translation strategy for seventeenth-century allographic translations of scientific works was the sense-for-sense approach, a strategy inherited from the Middle Ages and Renaissance (Bertrand 2015: 87; Chevrel et al 2014c: 1286). While scientific translators generally shared the literary translators' desire for clarity, they differed in other significant respects: their focus was on the clear and accurate transmission of scientific knowledge

[30] The translations undertaken by d'Ablancourt and his fellow translators are often referred to as 'belles infidèles' [beautiful but unfaithful]. The term was originally coined in the late seventeenth century to describe one of d'Ablancourt's translations but, in the twentieth century, became a critical historical term for the style of translation described in this section (Tran-Gervat and Weinmann 2014: 251; Tran-Gervat 2014: 382).

in a way that ensured it was clearly understood by the intended audience, rather than on imagination, elegance of style and enhancement of the French language (Chevrel et al 2014c: 1286; Bret and Moerman 2014: 606–07). Precision was vital: in the *De la traduction* (1635), Bachet de Méziriac, the translator of the *Arithmetica* (1621) of Diophantus of Alexandria (*fl*. 250 CE) from Greek to Latin, criticised Amyot for his lack of fidelity to original texts and the mistakes in his translations, caused by a lack of knowledge of a range of subjects, including zoology and mathematics (Zuber 1968: 57; Ballard 1998: xxviii–xxxiv). Knowledge of the subject matter being translated was absolutely essential (Bret and Moerman 2014: 607). The focus on accuracy did not mean that literal translation was acceptable, however: it was only to be used for translating scientific or technical vocabulary directly from Latin (Tran-Gervat 2014: 384). The lack of adherence to the literal approach can be seen in other aspects of scientific translation too: in addition to translating for meaning, translators added to the translated work, updated it, annotated it, interpreted, explicated and disagreed with it where necessary (Bret and Moerman 2014: 606; Chevrel et al 2014c: 1286). This approach can be seen in Mersenne's translations of the work of Galileo Galilei (1564–1642), as noted in chapter 4, and in many of the ancient Greek works translated in successive waves of translation up to and including the seventeenth century. As will be seen in the next section, the most important feature of the translation of scholarly work of any kind was its role in the transmission of knowledge between cultures (Bret and Moerman 2014: 607, 609).

2.2 Developments in mathematics

2.2.1 The role of translation in the transmission of mathematics

As Fransen has noted, '[t]he history of Early Modern science is strongly connected to translation' (2017a: 3). This phenomenon had two dimensions. On the one hand, 'translation was at the core of scientific exchange' during the Early Modern period (Fransen 2017a: 3), including self-translation of the kind exemplified by the case-study texts. On the other, Early Modern European science was built on a foundation of knowledge acquired from mediaeval and Renaissance translation movements (Fransen 2017a: 3–4). Throughout history, translators have transformed texts from other cultures, using them to enrich the receiving culture and stimulate it to advance knowledge, particularly in science (Salama-Carr 1995: 123). This was as true for seventeenth-century France as it had been for previous societies.

Before the Renaissance, the most significant route by which mathematics reached western Europe was through the Islamic world of the eighth to eleventh centuries CE. From the end of the eighth century, a translation programme based at the 'House of Wisdom' in Baghdad ensured that manuscripts containing many of the classic Greek mathematical texts retrieved by scholars fleeing Athens and Alexandria were translated into Arabic, including the principal ancient Greek works of Euclid (*fl. c.* 295 BCE), Archimedes (*c.* 287–*c.* 212 BCE), Diophantus and Claudius Ptolemy (*c.* 100–*c.* 170 CE), along with works translated from Persian and Sanskrit (Katz 2014: 267; Merzbach and Boyer 2010: 205). It is likely that considerably more ancient science and mathematics would have been lost but for this translation programme (Goodman and Russell 1991: 16). The Islamic scholars, most notably Abū Ja'far Muhammad ibn Mūsā al-Khwārizmī (before 800–after 847 CE), took these ancient works and used them as the basis for their own mathematical innovation, particularly in algebra and its relation to arithmetic, using the newly discovered Indian numerals (Montgomery 2000: 135; Merzbach and Boyer 2010: 206).

The new mathematics of Islam and the works translated from ancient Greece formed part of the transmission of learning to mediaeval Europe in the twelfth century that sparked a revival in mathematics that promoted innovation, first in Italy and later throughout Europe (Katz 2014: 328–30; Merzbach and Boyer 2010: 226). European scholars had been aware that there was an ancient Greek mathematical tradition, but had no access to it. The situation was altered by the efforts of twelfth-century schools of translators based in Spain after the *Reconquista* [Reconquest] and in Sicily, and by William of Moerbeke (1215–1285/86) in thirteenth-century Rome (Rose 1975: 76; Katz 2014: 328). While the translators in Spain generally used the Arabic versions of ancient Greek text recovered from Arabic libraries, those based in Sicily worked principally from the original Greek texts, to which they had access (Rose 1975: 77). The most important mathematical translations carried out in Toledo, Barcelona and Toulouse included those of al-Khwārizmī's work on arithmetic by

Johannes Hispalensis (John of Seville) (*fl.* 1130s–1140s) and Adelard of Bath (*fl.* 1116–1142), al-Khwārizmī's *Algebra* by Robert of Chester (*fl. c.* 1141–*c.* 1150) and Gerard of Cremona (*c.* 1114–1187), Euclid's *Elements* from Arabic into Latin by Adelard, Robert and Gerard, Ptolemy's *Almagest* (originally known as the *Syntaxis mathematica*, or Mathematical Syntax) from Greek into Latin by Adelard and Gerard, Archimedes' *On the Measurement of the Circle* by Plato of Tivoli (*fl.* 1132–1146) and Gerard, and works by Autolycus of Pitane (*fl. c.* 300 BCE), Theodosius of Bithynia (fl. second half of second century BCE) and Menelaus of Alexandria (*fl. c.* 100 CE) (Katz 2014: 328–29; Merzbach and Boyer 2010: 226–27; Folkerts 2006: III, 7–18; Rose 1975: 77–78; Clagett 1981: 226). The translators in Sicily produced Latin versions of Ptolemy's *Almagest* and *Optica* [Optics], amongst others, while William translated works by Proclus (410/412–485 CE), Ptolemy and Hero of Alexandria (*fl.* 62 CE), along with most of Archimedes' works. William's translations of Archimedes were used by scholars in the Middle Ages (Clagett 1981: 228), and formed the basis of retranslations in the Renaissance (Rose 1975: 80).

Charles Burnett has suggested that the driving force behind this translation project was the desire of the newly founded universities across Europe for access to ancient texts (2001: 254). The project's focus was on filling the gaps in European knowledge of the ancient Greek legacy, particularly in rhetoric, dialectic, geometry and astronomy, and gaining knowledge of topics that were only known to the Islamic scholars, such as algebra (Burnett 2001: 257–59). According to Montgomery, this project bore a lot of similarities to the Islamic programme of the House of Wisdom, including the large scale of work involved, the choice of subject matter, based on science and philosophy, and the sense that the project involved the discovery and appropriation of great wealth from previous civilisations that could be used for new purposes (2000: 142). Its impact was similar: textual culture was greatly enriched, a stimulus was provided to scholarly writing, new vocabularies were created and the language greatly enriched (Latin in this instance), and new educational institutions were supported (the universities in this case) (Montgomery 2000: 142). There is some evidence that the rediscovered texts supported mathematical innovation, for example providing knowledge to Leonardo Fibonacci (also known as Leonardo of Pisa, *c*. 1180–*c*. 1250) that subsequently made its way into his

Liber Abaci [Book of Calculation] (1202), but the momentum for new mathematics was not sustained (Rose 1975: 79). In addition, 'several major traditions of Greek mathematics, particularly those of Apollonius, Diophantus, Hero and Pappus' and much of Archimedes' work were not recovered by the mediaeval translators (Rose 1975: 84).

The next significant period of translation of scientific texts involved translation from Latin into the Romance vernaculars, and began at different stages in the thirteenth and fourteenth centuries, depending on the language. Scientific translation into French began in the thirteenth century but expanded greatly in the fourteenth (Ducos 2008: 181). The first major French school of translation was set up by Charles V in the late fourteenth century (Ballard 2007: 84). Oresme, Charles's principal translator, translated ancient Greek works, including those by Aristotle (384–322 BCE) and Ptolemy (Nama 1995: 36–37). By the end of the fifteenth century, dozens of the ancient Greek scientific treatises available in Latin had been translated into French (Shore 1989: 297). The translation of specifically mathematical texts was slow, however: only three were translated into French before the fifteenth century, a number that rose to approximately fifteen during that century (Toniato 2008: 248–49). As with previous translation projects, the purpose behind the mediaeval project was the appropriation and transmission of knowledge, this time for the benefit of a larger, French-speaking audience, and to demonstrate that the vernacular could be used for scientific texts (Ducos 2008: 182–83).

The final translation movement of significance to mathematicians in seventeenth-century France was the programme initiated in the Renaissance to recover the most important works of Antiquity, including those not discovered during the Middle Ages. Daniel Russell believes that, in common with all previous translation movements, this programme can best be understood as a concerted effort to appropriate the texts from previous cultures for the needs and benefit of the target culture (2001: 29). Within mathematics, this manifested itself as a desire on the part of mathematicians, with the support of humanist scholars, to restore the subject to a prominent position in learning, a mission articulated at various times in sixteenth-century Italy by mathematical translators such as Bartolomeo Zamberti (*c.* 1473–after 1543), Francesco Maurolico (1494–1575) and Federico Commandino (1509–1575) (Rose 1975:

1–2, 51, 165, 205). The translation programme was facilitated by the creation in the fifteenth century of humanist libraries in Florence, Rome, Venice and other Italian cities to house Greek manuscripts sought and found in, amongst other locations, Italian monasteries in the early part of the century and in Constantinople following its fall in 1453 (Rose 1975: 26–56). While mediaeval libraries had contained very few mathematical works beyond Latin versions of Euclid and Archimedes, the new libraries contained important Greek texts by Apollonius of Perga (second half of third century–early second century BCE), Diophantus, Proclus, Hero and Pappus of Alexandria (*fl.* 300–350 CE), amongst others (Rose 1975: 26).

Large-scale translation from Greek to Latin began in Italy in the middle of the fifteenth century in the school of translators set up in Rome by Pope Nicholas V (1397–1455) (Ballard 2007: 94–96; Rose 1975: 28). The most significant translation from this school was of Archimedes' works, carried out around 1450 by Jacopo de San Cassiano (Jacobus Cremonensis) (1393 to 1413–1453/1454) and corrected by Johannes Regiomontanus (1436–1476) in 1462 (Rose 1975: 30–31, 39). These translations began to increase awareness of Archimedes' work in Europe (Clagett 1981: 229). Regiomontanus also translated works by Apollonius, Hero and Ptolemy into Latin (Merzbach and Boyer 2010: 246–47). In general, however, very few of the Greek manuscripts collected in the new humanist libraries were translated before the sixteenth century (Rose 1975: 56).

Although there were more translations of mathematical texts in the early years of the sixteenth century, it was not until later in the sixteenth century that most were carried out (Boas 1962: 226). Many were retranslations, based on both mediaeval and earlier Renaissance translations that had often been undertaken by non-mathematicians (Katz 2014: 409), and many resulted in extensive reworking of the original texts. The most prolific translators were Maurolico and Commandino. Both men criticised the inadequacy of early Renaissance translations and decided to carry out programmes of what they perceived as much-needed higher quality new translations based on a secure understanding of both Greek and mathematics (Rose 1975: 53, 203–08). Maurolico's translations, carried out mainly in the 1630s and 1640s, were aimed at restoring the works of Euclid, Apollonius and Archimedes, particularly the latter two (Rose 1975: 165). His practice in producing a version of the first four books of Apollonius's *Conics* and Archimedes' major works involved what Paul Rose characterises as 'a full-scale reorganisation' (1975: 166). His approach to Apollonius's work, for example, involved reworking the *Conics* to ensure greater understanding of the mathematical content; in order to achieve his goal, he added to and edited the text, omitting proofs when he considered it necessary to do so. The result, in Rose's view, was the first progress in the theory of conic sections since Antiquity (Rose 1975: 166).

Commandino also reworked the *Conics* (1566), revising the first translation of the work, produced by Giovanni-Battista Memmo (*c.* 1466–1536) and published in 1537, but considered flawed (Toomer 1990: xxi). With the new text, Commandino also published the commentary on the *Conics* by Eutocius of Ascalon (born *c*. 480 CE) and *On the Section of a Cylinder* and *On the Section of a Cone* of Serenus (*fl*. fourth century CE), alongside his own commentaries (Fried and Unguru 2017: 8). Modern scholars are of the view that Commandino's retranslation, based on a more profound understanding of the text than the previous version on which it was based, superseded earlier translations of the *Conics* and remained the standard version for the following hundred-and-fifty years (Rosen 1981: 364; Fried and Unguru 2017: 8; Toomer 1990: xxi). Commandino's practice in translating Archimedes' *On Floating Bodies* was similar: he used William of Moerbeke's translation as a starting point, emended errors in both William's translation and the original Greek manuscript that they both used, and added in proofs from the *Conics* to explain facts that Archimedes treated as assumed knowledge but which were unfamiliar to Renaissance mathematicians (Rose 1975: 200–01; Clagett 1981: 227–29). Commandino also produced Latin translations of the rest of Archimedes' works (1558), Ptolemy's *Planisphærium* [Planisphere] (1558) and *De Analemmate* [On Sundials] (1562), Euclid's *Elements* (1572), Autolycus's *De Ortu et Occasu* [On Rising and Setting] (1572), Hero's *Pneumatica* [Pneumatics] (1575), and Pappus's *Mathematical Collection* (1588), accompanying many of his editions with his own commentaries (Merzbach and Boyer 2010: 272; Katz 2014: 409; Rose 1975: 205; Rosen 1981: 364).

The best known and most widely read and studied of the ancient Greek texts to be retranslated was Euclid's *Elements* (Katz 2014: 51, 426): twenty-five

Latin translations appeared between 1482 and 1606 (Giacomotto-Charra 2015: 785). The first published edition of a complete Latin text of the *Elements* based on the original Greek text was prepared by Zamberti and was published in Venice in 1505, along with Euclid's *Phænomena* [Phenomena], *Catoptrica* [Catoptrics], *Optica* [Optics] and *Data,* which, at that time, were barely known (Folkerts 2006: III, 29–30; Rose 1975: 51). The Greek text of the *Elements* was first printed in an edition prepared by German theologian Simon Grynaeus (1493–1551) in 1533 and accompanied by the commentary written by Proclus in the fifth century CE. The best-known edition of the *Elements* in seventeenth-century France was the Latin version prepared by Clavius and first published in 1574 (Mesnard 1991a: 376). This edition is described by scholars as not so much a translation as a comprehensive work containing rewritten proofs and notes from previous commentators, editors and Clavius himself (Heath 1956: 105; Murdoch 1981: 451; Busard 1981: 311). Clavius's practice, like that of Commandino, exemplifies an approach that considers the key consideration in translating mathematical works from other cultures to be the transmission and acquisition of knowledge. As will be seen in chapter 3, Clavius's practice is significant for Hérigone's *Cursus* because, not only does his version of the *Elements* take up most of the first volume of Hérigone's work, but it suggests, in the same ways as the *Cursus*, that notions of authorship and intellectual copyright were freer at this time than they would later become.

The other significant work to be recovered and translated in the sixteenth century was Diophantus's *Arithmetica*. Regiomontanus rediscovered the Greek text in the 1460s, but did not manage to translate it (Heath 2014: 42). It came to the notice of Rafael Bombelli (1526–1572) after he had published the first edition of his *Algebra* (1569); he incorporated some of it into the second edition (1572) but did not succeed in publishing a translation on which he was collaborating before his death (Heath 2014: 42–44; Rose 1975: 146–47, 208).[31] The work was translated into Latin for the first time in 1575, by Wilhelm Holtzman (1532–1576), known as Wilhelm Xylander, with a commentary by the translator (Vogel 1981: 117; Heath 2014: 45–49). A corrected version of Xylander's Latin translation was published with the original Greek text for the first time in 1621 by Bachet de Méziriac, and had a profound effect on Pierre de

[31] The development of algebra, and the role of Diophantus's work in that process, will be dealt with more fully in section 2.2.4 below.

Fermat (1601–1665).[32] The recovery of the *Arithmetica* also had a significant impact on the work of Viète (Rose 1975: 147), and subsequently, through Viète's work, on Descartes and Hérigone, as will be seen in chapter 3.

By the time of Commandino's death in 1575, most of the major mathematical works of Antiquity had been recovered and translated into Latin. Between them, Commandino, Maurolico and Regiomontanus had focused in particular on the works by the most important Greek mathematicians: Euclid, Archimedes, Apollonius, and Diophantus (Rose 1975: 214). By the end of the sixteenth century, some of the more important works had also been translated into the major European vernacular languages: English, German, French, Italian, and Dutch (Merzbach and Boyer 2010: 271–73). Among the first were translations of the *Elements*. The earliest translations into Italian were made before 1500 and were based on Latin translations from Arabic translations. The first Italian translation based on Zamberti's Latin translation was made by Niccolò Tartaglia (1499/1500–1557) in 1543. Translations into German, English and French followed during the next three decades; the first French translation, undertaken by Forcadel, was published in Paris in 1564 (the first six books) and 1565 (the next three) (Folkerts 2006: III, 30–32; Giacomotto-Charra 2015: 785). In the sixteenth century, it was only considered appropriate to translate into the vernacular languages those books that had practical applications; the first complete French editions of the *Elements* were therefore not published until the early seventeenth century, by Didier Dounot (1609) and Henrion (first edition, 1614). In the first volume of the *Cursus*, Hérigone makes use of Henrion's French translation of Clavius's Latin version of the first fifteen books of the *Elements*.

Forcadel also translated into French and commented on two of Archimedes' works, including *On the Equilibrium of Planes*, in 1565, as well as contemporary works by Fine and Reiner Gemma Frisius (1508–1555) (Clagett 1981: 229; Giacomotto-Charra 2015: 784, 791). The other French translation of significance for this thesis involved the first four books of Diophantus's *Arithmetica*, first translated into French from Xylander's Latin translation by Simon Stevin (1548–1620) as part of his *Arithmétique* in 1585 (Zilsel 2013: 50;

[32] It was in his copy of Bachet de Méziriac's version of the *Arithmetica* that Fermat wrote comments, including the one now generally referred to as 'Fermat's last theorem' (Singh 1998: 62–66).

Giacomotto-Charra 2015: 784). Violaine Giacomotto-Charra characterises Stevin's French version of the *Arithmetica* as an adaptation featuring Stevin's own algebraic notation and demonstrations.[33] As will be seen in chapter 3, Hérigone also adapted some of Diophantus's examples for his own use in his chapters on algebra and used Stevin's works throughout the *Cursus*. In addition, Hérigone's work shows another important development in translation at the end of the sixteenth century and the beginning of the seventeenth century: the translation into French of original, innovative mathematical work composed in Latin. Alongside Henrion's translation of Clavius's work into French, Hérigone also refers to the 1630 translation of Viète's algebraic work into French by Antoine Vasset (1598–1678) and the 1634 translation of the 1586 Latin translation undertaken by Willebrord Snel (1580–1626) from the original Dutch of Stevin's *Van de weeghconst* [On the Art of Weighing] (collected in Stevin 1955) by Albert Girard (1595–1632) as *L'Art pondéraire, ou La statique* [The Art of Weighing, or On Statics].[34]

Translation of the major Greek mathematical texts had a positive impact on mathematical research into the seventeenth century. As well as the influence of Xylander's translation of Diophantus's *Arithmetica* on Viète's work on algebra noted above, Commandino's translations of Archimedes' *On Floating Bodies* and *On the Equilibrium of Planes* are known to have had a strong influence on Galileo's work on dynamics and statics (Grendler 2002: 413). Furthermore, research on conics flourished following translation of the first four books of Apollonius's *Conics* (Rose 1975: 214). In particular, Maurolico's attempt to reconstruct the lost fifth book of the *Conics* began a trend in reconstruction of lost works, particularly the *Conics*, that led to much of the seventeenth-century innovation in geometry (Merzbach and Boyer 2010: 128, 272). According to Gerald Toomer, '[i]t is hard to overestimate the effect of Apollonius on the brilliant French mathematicians of the seventeenth century, Descartes, Mersenne, Fermat, [...] Desargues and Pascal' (1981: 191). Parts of the *Conics*, reconstructed by Viète, Snel and Marino Ghetaldi (1566/1568–1626), can be found at the end of the first volume of Hérigone's *Cursus*. By the time the lost

[33] It should be noted, however, that Kurt Vogel describes Stevin's version of the first four books of the *Arithmetica* as 'a free French rendering', while Heath dismisses Stevin's efforts as a 'so called "Translation"' (Vogel 1981: 117; Heath 2014: 55).
[34] Antoine Vasset is thought to be a pseudonym used by Claude Hardy (O'Connor and Robertson 2010), so the dates given for him are Hardy's.

books of the *Conics* had been recovered in Europe (1629), printed (1661) and translated from Arabic (1710), their content had been superseded by the efforts of the seventeenth-century mathematicians (Toomer 1990: xxi).

By contrast with the sixteenth century, apart from translations of the *Elements*, relatively few of the works translated from the classical languages in the early seventeenth century were texts from Antiquity; instead they mostly consisted of practical handbooks and treatises, some translated for the first time, others edited for republication (Juratic 2014: 193; Bret and Moerman 2014: 619–20). According to Burke, the first half of the seventeenth century was the peak period for a trend that had begun in the sixteenth century: translations in the opposite direction, from the European vernacular languages into Latin (2007a: 21). Science was one of the three main categories of books translated into Latin during this period, along with religious and historical texts (Burke 2007b: 71–73). This change in Latin's role, from source language to target language, had its origins in its status as the language of the Republic of Letters: where previously most works had been written in Latin and were thus available to scholars across Europe, the translations into Latin meant that scholars could gain access to learning that was written in vernacular languages they did not necessarily read (Burke 2007a: 22). Burke provides examples from the sixteenth and seventeenth centuries including Theophrastus Paracelsus (1493–1541), Galileo, Matthias Bernegger (1582–1640), Robert Boyle (1627–1691), and Isaac Newton (1642–1727), all of whom widened their academic audience as a result of translation into Latin, whether or not they intended or wanted to do so (2007b: 73–74). To this list could be added two examples cited above: Descartes's *Geometria*, originally published as *La Géométrie*, and Snel's Latin translation of Stevin's *Van de weeghconst*.

Finally, as Patrice Bret and Ellen Moerman note, there were other scientific texts, or extracts of texts, that were translated into French during this period but were never published, for a variety of reasons, because the translator did not find a publisher or because the content was either for personal use only or had been superseded by the time it was ready for publication (Bret and Moerman 2014: 612–13). Unpublished translations of scholarly works written during this period include French versions of Galileo's works, translated by Bernard Frenicle de Bessy (*c.* 1605–1675) and others, and Mersenne's translation of a musical work by Bacon (Crombie 1994: II, 867; Fabbri 2007: 292). The translators of these works will almost certainly have passed on the ideas developed in the translated texts to members of their intellectual circles and used them in their own works.

This section has shown that translation has been crucial in disseminating mathematical knowledge throughout recorded history. The wider significance of the three case-study texts lies in their place within this historical tradition: by translating their own works, the authors ensured their works were able to reach audiences that would otherwise not have benefitted from their knowledge. Three other mathematical developments linked to the transmission of mathematics contributed to the authors' ability to communicate their work more effectively: methods of convincing and persuading readers of the truth of mathematical statements, developments in mathematical terminology, and the use of algebraic symbols and arithmetic signs.

2.2.2 Proof and persuasion in mathematical writing

In his survey of proof and persuasion in Early Modern science, Richard Serjeantson concludes that 'mathematics — and, in particular, geometry — had a privileged place with respect to the certainty of its proofs' (2006: 154). In the sixteenth century, attempts were made to question the nature of mathematical certainty on the grounds that mathematical demonstrations did not meet the requirements of syllogisms in Aristotelian logic. Clavius in the sixteenth century and Christoph Scheiner (1573–1650) in the early seventeenth both 'reasserted the scientific status of mathematics on the basis of its demonstration of conclusions "by axioms, definitions, postulates, and suppositions"' (Serjeantson 2006: 155, including a quote from Scheiner). Part of the seventeenth-century view of logical reasoning was disapproval of syllogisms in science in general (Nuchelmans 2000: 132). In its place, Bacon advocated the use of inductive reasoning in his work and Descartes promoted the use of the natural light of reason in the *Regulæ ad directionem ingenii* [Rules for the Direction of the Natural Intelligence] (1628–29) and *Meditationes de prima philosophia* [Meditations on First Philosophy] (1641) (Nuchelmans 2000: 132; Boyle 1999: 601). Both methods of reasoning can be seen in Pascal's work and will be discussed in chapter 5: the first fully explicit formulation of mathematical induction can be found in the treatises on the Arithmetic Triangle, while Pascal's rhetorical method, as expounded in the two parts of *De l'esprit géométrique* [On the Geometric Spirit], written in the late 1650s, includes his own notion of 'lumière naturelle' [natural light].

Mathematical demonstrations in the sixteenth century were examples of deductive reasoning based on Proclus's commentary on Euclid's practice in the *Elements* (Bertato 2018: 112). As will be seen in the relevant chapters below, Hérigone used Proclus's writings on mathematical demonstrations to set out his mathematical method in the *Cursus*, while Pascal's demonstrations follow the same pattern. Proclus divided demonstrations into six constituent parts: the enunciation; the exposition, or setting out; the definition of a goal; the construction, or preparation; the proof, or demonstration; and the conclusion (Netz 1999a: 284–85; Bertato 2018: 112).[35] Within the movement from one part of the proposition to the next, repetition of language provides the generalisation in mathematical demonstration as a substitute for explicit proof (Netz 1999b: 269). Although mathematical induction also uses repetition to provide generalisation, the repeatability in this instance is proved explicitly (Netz 1999b: 269).

The status of mathematical demonstration became stronger in the seventeenth century than it had been in the sixteenth, as it was seen as 'the surest form of natural proof' for those parts of the natural world structured around mathematics (Serjeantson 2006: 155–56). The certainty provided by mathematical demonstrations was based on 'the prestige of geometry as the only truly demonstrative science', and formed the basis of Pascal's mathematical method in *De l'esprit géométrique* (Serjeantson 2006: 156). Pascal's search for a method was, in Serjeantson's view, part of the ambitious quest in the Early Modern period for 'theoretical accounts of how knowledge is obtained and demonstrated' (2006: 140). The best-known example was Descartes's *Discours de la méthode* [Discourse on Method], published in 1637. Pascal's own theory of knowledge, which considered both proof and rhetoric,

[35] The six parts of Proclus's division were known in Greek as the *protasis*, *ekthesis*, *diorismos*, *kataskeue*, *apodeixis* and *sumperasma* (Netz 1999a: 284–86). The similarity with the six parts of a speech in rhetoric is noteworthy: in Latin, they are the *exordium* [introduction], *narratio* [statement of facts], *partitio* [division of the points at issue], *confirmatio* [proof], *refutatio* [refutation], and *conclusio* [conclusion] (Vickers 1988: 68–71). Reviel Netz notes that this structure is not as rigid as Proclus implies: it may be abbreviated and the order of the parts altered, but it retains a stable 'kernel' (1999b: 253).

was never completed and was not published until long after his death. It did, however, provide a rationale for his composition of the treatises on the Arithmetic Triangle, as will be seen in chapter 5.

Pascal's linking of mathematical certainty with rhetoric stood in contrast to much Early Modern thinking about demonstration and proof: logical mathematical demonstrations were considered to be rational and universal, while rhetoric was associated with persuasive argument which, by its very nature, was mutable and therefore not part of scientific argument (Serjeantson 2006: 135–37). Serjeantson concludes that it is difficult to assess the position of rhetoric in Early Modern science as a whole but believes that rhetoric may have increased in significance in the sixteenth and seventeenth centuries despite the prestige afforded to mathematical proof (2006: 153–54). As will be seen in the case studies, Hérigone, Mersenne and Pascal all used a range of rhetorical techniques in their writing.

Part of the rhetorical repertoire of the case-study mathematicians was what is now referred to as 'mathematical rhetoric'. According to a group of scholars that has emerged since the late 1980s and which is referred to by Paul Ernest as the 'rhetoric of the sciences movement', rhetoric has always been used in mathematics, despite the primacy of rigour and certainty in mathematical proof. Scholars of scientific rhetoric use the term 'rhetoric' 'to indicate that style is inseparable from content in scientific texts' (Ernest 2013: 75). Within mathematics, interest has grown along with the realisation that '[m]athematics has rhetorical features that scholars have almost entirely ignored' (Reyes 2004: 163). And, as John Fauvel notes, while it might sound strange to discuss rhetoric in connection with mathematics, just as it would have done in the seventeenth century, 'what is meant is just a concern for how language is used in communicating mathematics' (1988: 25).

Ernest believes that 'rhetorical form plays an essential part in the expression and acceptance of all mathematical knowledge' (1998: 174). John Nelson et al explain how rhetoric is used in mathematics: '[s]cholarship uses argument, and argument uses rhetoric. The "rhetoric" is not mere ornament or manipulation or trickery. It is rhetoric in the ancient sense of persuasive discourse' (1987b: 3). Mathematicians use 'rhetorical modes of argument and persuasion, in addition to purely formal or logical procedures' (Davis and Hersh 1987: 54). Mathematics as it is actually practised is therefore seen as a form of social interaction where proof is delivered using a mixture of 'the informal, of calculations and casual comments, of convincing arguments and appeals to the imagination and the intuition' (Davis and Hersh 1987: 68). In this way, if rhetoric is seen in its usual definition as 'natural discourse which serves to convince', mathematical rhetoric is 'common language put to the purpose of convincing us that something or other about mathematics is the case' (Davis and Hersh 1987: 59).

Philip Kitcher, along with Philip Davis and Reuben Hersh, provides examples of what mathematical rhetoric might mean in practice. Kitcher states that mathematical proofs contain rhetorical forms in the shape of standard structures and phrases that help readers to understand them; in fact, without any explicit commentary, he believes that proofs would often be difficult to understand (1995: 53). Davis and Hersh give examples of rhetorical phrases, or 'rhetoric in the service of proof' as they characterise them, that serve the purposes identified by Kitcher, including such phrases as 'It is easy to show that ...' and 'By an obvious generalization ...' (1987: 60). Phrases of this type not only improve the intelligibility of mathematical proofs and arguments, but also serve the rhetorical function of convincing the reader that the move from one step to the next is logical and comprehensible.

The 'rhetoric of the sciences movement' is mainly concerned with the use of rhetoric in modern mathematical argument. It is nevertheless applicable to seventeenth-century mathematics, as made clear by Serjeantson above. In common with their peers, all three mathematicians in the case studies used mathematical demonstrations prominently in their work, alongside what could be termed as phrases of mathematical rhetoric according to the definition provided above. Consequently, analysis of their work in accordance with Proclus's division of demonstrations and Davis and Hersh's definition of mathematical rhetoric will form a significant part of my analysis of their work in the next three chapters. Consideration of the mathematical terminology used in both Latin and French in the three pairs of work will also form a significant part of all three case studies.

2.2.3 Mathematical terminology

According to Menso Folkerts, '[t]he development of mathematical terminology in the Latin Middle Ages has not yet been systematically investigated', with the consequence that there is no single source for information on the etymology of Latin mathematical terms (2005: 149). The same also appears to be true for French terms: Bertrand Hauchecorne describes the amount of information on mathematical terminology as 'sparse' (2003: 223). Instead, research depends on searching for word origins in a small number of articles and etymological dictionaries (Folkerts 2005: 149; Hauchecorne 2003: 223). Non-specialist etymological dictionaries do not always separate mathematical meanings of vocabulary from general meanings and do not always include dates of first use, so it has not always been possible to trace the history of the terminology found in the case-study works with certainty.[36] In the majority of cases, that has not been a problem, as the terms were well-established by the seventeenth century. I have indicated where terminology was not fixed in Latin or French by the time the case-study texts were written. As will be seen in chapter 4, this was the case for the terminology regarding combinations, one of the mathematical topics linking the three case studies, which, according to Descotes, was still somewhat haphazard in the 1630s (2001b: 44).

Mediaeval Latin terminology came from two principal sources: on the one hand, classical Latin terminology, which included translations, calques and borrowings from Greek, and, on the other, translations and borrowings from Arabic, some of which originated in Greek and Indian mathematics (Hughes 1996: 348–49; Folkerts 2005: 149). From the first source, particularly the fifth-century translation of the *Elements* by Anicius Manlius Severinus Boethius (*c.* 480–524/525 CE), came the arithmetic operations 'addere', 'subtrahere', 'multiplicare' and 'divider' [add, subtract, multiply, divide], number-related terms, including 'numerus', 'duo', 'secundus', 'bini' and 'duplum' [number, two, second, twice, double], geometrical vocabulary such as 'punctum', 'linea', 'angulus', 'area' and 'quadratum' [point, line, angle, area, square], and terms to describe

[36] The sources I have used to investigate French terms include Hauchecorne's etymological dictionary of mathematical terms (2003), and two etymological dictionaries: *Le Petit Robert* (1983) and the database on the website of the Centre National de Ressources Textuelles et Lexicales (CNRTL: 2012) (see bibliography). Full details of the dates of first use of the French terms can be found in appendix 3.

mathematical activity, such as ‘lemma’ and ‘mathematicus’ [lemma, mathematics] (Hughes 1996: 348; Hauchecorne 2003: 8; Folkerts 2005: 151–52). From the second, particularly Robert’s translation of al-Khwārizmī’s *Algebra*, came terms, many originally from Greek, such as ‘radix’, ‘cubus’, ‘zero’ and ‘algebra’ itself [root, cube, zero, algebra] (Folkerts 2005: 159; Lo Bello 2013: xi). More vocabulary entered mediaeval and Renaissance Latin as a result of successive translations, including ‘demonstrare’ [demonstrate] in Adelard’s thirteenth-century translation of the *Elements*, and further arithmetical terms such as ‘additio’, ‘divisio’, ‘multiplicatio’ and ‘subtractio’ [addition, division, multiplication, subtraction] (Hughes 1996: 348; Lo Bello 2013: xii).

Much French mathematical terminology is derived from Latin and Greek, two languages that were long viewed as highly prestigious sources of vocabulary (Hauchecorne 2003: 7). Terms from Latin in particular began to emerge in the Middle Ages with translations from Latin texts. The linguistic affinity between Latin and French meant that a significant amount of French terminology was modelled directly on the equivalent Latin terminology, including, for example, the cognates ‘multiplier’ for ‘multiplicare’ and ‘soustraire’ for ‘subtrahere’ (Descotes 2001b: 43, Toniato 2008: 254). By the Renaissance and the seventeenth century, more terminology was being created directly from original Greek texts as well as Latin (Hauchecorne 2003: 8). Historical developments in both Latin and French mathematical terminology, and the close link between them, play a significant role in the creation of the three bilingual case-study pairs of texts, as will be seen in chapters 3 to 5.

2.2.4 Algebra and the use of symbols in mathematics

Just as an understanding of developments in mathematical terminology and proof and persuasion before the seventeenth century is important to fully appreciate the case-study texts, so too is an understanding of the adoption of symbolism, both in algebra and arithmetic. As noted above, Islamic scholars made great progress in both algebra and arithmetic. They made use of translations of Greek texts, particularly Diophantus’s *Arithmetica*, where algebraic syncopation first appeared (Katz 2014: 186; Heeffer 2009: 1).[37] They also introduced a new number system, based on Indian arithmetic (Katz 2014:

[37] Syncopated algebra involves the use of symbols and abbreviations for the most frequently occurring quantities and operations (Mitchell 1911: 226). In his *Arithmetica*, Diophantus used symbols for subtraction, equality, the unknown quantity and lower powers of the unknown (Mitchell 1911: 227–28).

268–69; Merzbach and Boyer 2010: 206, 210). Following translation of the principal Islamic works into Latin in the twelfth century, adoption of the new algebraic and arithmetic methods and number system was slow (Merzbach and Boyer 2010: 228). Some limited initial progress was made by thirteenth-century mathematicians such as Fibonacci and Johannes de Sacrobosco (died 1244/1256) (Merzbach and Boyer 2010: 228–29). Some further progress was made by the fourteenth-century Italian 'maestri d'abaco', or 'abacists', who used the methods from the Islamic algebras translated from Arabic in the twelfth century to create algebra textbooks for schools (Katz 2014: 386).

It was not until the Renaissance that significant progress was made with algebra. As with the transfers of knowledge outlined above, progress during this period was partly initiated through translation, with the publication in 1494 of the *Summa de arithmetica* [Summary of Arithmetic] of Luca Pacioli (*c*, 1445–1517), a work which, despite its title, was written in the vernacular and which, amongst other material, compiled contemporary knowledge of arithmetic and algebra (Merzbach and Boyer 2010: 252). The algebra was based on the recent Italian translation of al-Khwārizmī's *Algebra* and Fibonacci's *Liber Abaci*, and featured increased use of syncopation, including the use of 'p' and 'm' for addition and subtraction, and 'co' for 'cosa', or the unknown, 'ce' for 'censo', 'cu' for 'cubo', 'cece' for 'censo di censo', and so on, to represent the square, cube, and 'square-square', or fourth power, and so on, of the unknown (Katz 2014: 388; Merzbach and Boyer 2010: 252). Despite the lack of original material in the *Summa*, Rose believes that it initiated the major advances in algebra in the sixteenth century (1975: 143–45).

Algebra progressed in Germany in the first half of the sixteenth century thanks to the work of Adam Riese (1492–1559), Christoff Rudolff (end of fifteenth century–first half of sixteenth century), Peter Apian (1495–1552) and Michael Stifel (*c*. 1487–1567). This progress was taken up by Italian algebraists in the second half of the century through the *Ars magna* [The Great Art] (1545) of Girolamo Cardano (1501–1576), which is considered to be the beginning of modern algebra (Merzbach and Boyer 2010: 255). Cardano used very little syncopation, expressing problems in words rather than symbols, solved individual rather than general problems, and thought of algebra in geometric terms, following al-Khwārizmī (Merzbach and Boyer 2010: 258). Publication of the *Ars magna* gave another tremendous stimulus to progress in algebra, most clearly seen in the work of Bombelli (Merzbach and Boyer 2010: 260–61). As noted above, many of the problems in Bombelli's work were taken from Diophantus's *Arithmetica* (Katz 2014: 186).

Problems from the *Arithmetica* are also a feature of the algebraic work carried out by Viète, the last mathematician to make progress with algebra before it was unified with geometry by Descartes and Fermat in the seventeenth century, and the source for Hérigone's sections on algebra in the second and sixth volumes of the *Cursus mathematicus*. European algebraists were skilled in manipulating algebra, but were unable to generalise techniques or results because of the lack of symbols for coefficients of terms.[38] Viète was the first to study the structure of equations by introducing a distinction between the concept of a coefficient, represented by a consonant, and the unknown quantity, represented by a vowel (Katz 2014: 412; Merzbach and Boyer 2010: 274). For the first time, families of equations rather than single examples could be considered together (for example, $Ax^2 + Bx = C$, rather than, say, $4x^2 + 5x = 26$ or $2x^2 + 7x = 85$ separately). However, although Viète considered coefficients, he did not represent them in this way: he used the addition and subtraction symbols and the symbols for parameters and unknowns, but the rest of his algebra consisted of words and abbreviations, including expressions such as 'A cubus' for A^3 and 'A quadratus' for A^2 (Merzbach and Boyer 2010: 274). The slow adoption of symbolism was a characteristic feature of mathematics in the Renaissance, as reflected in Viète's continued use of words and abbreviations. For many mathematicians, this reluctance extended to the most basic arithmetic operators.

The addition and subtraction signs in use today were first used in Germany at the end of the fifteenth century but were not universally adopted immediately (Cajori 1993: 235). The letters used by Pacioli and others were in competition with the modern standard signs until the seventeenth century, when use of the latter spread to Italy and then on to France thanks to their adoption by both Viète and Pierre de la Ramée (Petrus Ramus, 1515–1572) in the late sixteenth century (Cajori 1993: 236). The addition sign is thought to have

[38] Coefficients are simply the numbers or letters that act as the multiplier of the unknown terms. So, for example, in the equation $4x^2 + 5x = 26$, the coefficient of x^2 is 4 and the coefficient of x is 5.

originally been a copy of the representation of the word ‘et’, signifying ‘and’ and not ‘addition’, in Latin manuscripts (Cajori 1993: 230–31). As Adriano Cappelli notes, a sign similar to the arabic numeral 7, with a cross bar, represented ‘et’, alongside the ampersand (&) in mediaeval Latin manuscripts (1982: 13, 17). The sign seems then to have been transformed into a variety of Greek and Christian crosses in printed texts: Viète was one of the many users of the horizontal Christian cross, for example (Cajori 1993: 236). The origins of the subtraction sign are less clear and, despite its simplicity, its form was not standardised until after the seventeenth century (Cajori 1993: 232, 244).

Although the signs for addition and subtraction were well on their way to standardisation by the middle of the seventeenth century, the same was not true of the signs for multiplication and division. The ‘×’ sign was used in a number of different ways in mathematics until it was deployed as a symbol for multiplication for the first time by English mathematician William Oughtred (1574–1660) in 1631. Neither the ‘×’ sign, in Britain, nor the dot, in the rest of Europe, became the standard signs for multiplication until the eighteenth century (Cajori 1993: 266–68). The ‘÷’ sign was not standardised until after its introduction in 1659 by Swiss mathematician Johann Rahn (1622–1676), and then only in the English-speaking countries (Cajori 1993: 270–71). Earlier mathematicians had used a variety of symbols, including the capital letter D, a reversed letter D, and the fractional line, while the colon was later popularised by Gottfried Wilhelm Leibniz (1646–1716) and used across Europe (Cajori 1993: 269–72). As will be seen in chapters 4 and 5, Mersenne and Pascal preferred not to use symbols for these two operations.

The ‘=’ symbol had been used to represent equality since its introduction by Welsh mathematician Robert Recorde (*c*. 1510–1558) in the middle of the sixteenth century. The use of ‘=’ was not immediately fixed, however, as there were a number of competing symbols being used by mathematicians at the time; Recorde’s symbol did not appear in print again until 1618 (Cajori 1993: 298–99) and was not greatly used outside England until the 1650s and 1660s. Even then, the majority of European mathematicians at the time did not use any symbol at all (Cajori 1993: 304–05). Instead, ‘equality was usually expressed rhetorically by such words as *aequales*, *aequantur* [...] and sometimes by the abbreviated form *aeq*.' (Cajori 1993: 297). The sign did not gain general acceptance until the eighteenth century (Cajori 1993:305).

The use of all five signs mentioned here will be examined as part of the case studies in this thesis. As will be seen in the next chapter, Hérigone attempted, unsuccessfully, to introduce a wide range of symbols into mathematics as part of his mathematical method, including symbols for the basic arithmetic operators as well as algebraic symbols and a range of other symbols and abbreviations. Hérigone saw symbols and signs as a kind of universal language that could replace standard written language in mathematical demonstrations; their impact would also be to remove the need for translation between versions of demonstrations in his works. James Knowlson notes the similarity between the development of algebraic symbolism by mathematicians such as Hérigone, Viète and Descartes in the late sixteenth and early seventeenth century and attempts during the same period to establish universal language schemes (1975: 22). Although Hérigone's enthusiasm for symbolisation was not shared by all mathematicians, including Mersenne and Pascal, examination of Pascal's works in chapter 5 will show that, in general, he used symbols and signs in the same ways in both languages – any differences in usage provide interesting insights into his approach to the two versions of his work – while, as I will show in chapter 4, Mersenne was interested in universal languages from a combinatorial perspective (Knowlson 1975: 69).

Implicit in both of the previous sections has been the presence of audiences for the mathematical works being translated, published and disseminated in the period prior to the middle of the seventeenth century. The next section will examine two significant historical trends that helped create the audiences for mathematical works in France and across Europe during this period, including the case-study works.

2.3 Audiences

A significant reason for the approximate equilibrium noted above between mathematical works published in Latin and French in the first half of the seventeenth century was the nature of the audiences for the works. There can be no doubt that Febvre and Martin are correct in stating that '[i]t was the intended audience above all that determined the choice of language used by the writer' (1976: 331). The choice faced by authors of mathematical works in particular was summarised by Descartes in a letter to Girard Desargues (1591–1661), written in 1639, as 'écrire pour les Doctes' [write for the Scholars] or 'écrire pour les Curieux qui ne sont pas Doctes' [write for the Curious who are not Scholars] (1659: 170). Descartes's 'Doctes' included the members of the European Republic of Letters, whose *lingua franca* was Latin, while his 'Curieux' consisted of the growing number of more highly educated Frenchmen, who were not necessarily expert in science and mathematics or fluent in written Latin but were attracted to the growing number of scientific *cabinets* and academies that emerged in France in the first half of the seventeenth century and where French was the language of discussion. As noted in the previous chapter, Miglietti identifies further audiences: in the seventeenth century context, this included the non-French members of the Republic of Letters who read French and members of the *cabinets* who were comfortable reading about science and mathematics in both Latin and French and so belonged to both of the other audiences identified (2019: 225). It should of course be noted that the four audiences identified by Descartes and Miglietti were, as suggested by Febvre and Martin, all *potential* audiences envisaged by the authors of mathematical texts and not necessarily the actual audiences who read the works. This section will examine two of the factors that created these potential audiences: the changes to the education system that helped produce a French audience of 'Curieux', and the factors that led to the emergence of the Republic of Letters, with its largely Latin-reading audience, and the growth of the French academies, including a bilingual, bicultural audience.

2.3.1 The education system

A significant trend in the creation of audiences for mathematical books in seventeenth-century France was education. A number of features of the educational system and the educational experiences of its scholars are relevant in this context: the availability of education at all levels, the curriculum on offer, the teaching and use of languages, levels of literacy, and opportunities for learning about science in general and mathematics in particular. In discussing education in and before the seventeenth century, however, a caveat must be borne in mind: as Anthony Grafton has pointed out, research into the education system in Early Modern France has revealed what opportunities were available, but not what occurred in individual settings (1981: 37–38). This means that the following account of the education system describes the education that was provided, albeit to a minority of young men only; it does not recount the extent to which they benefitted from it.

By the seventeenth century, there was a range of educational provision in France, none of it compulsory, and most associated with the Church (Phillips 1997: 76). Attendance at a specific type of educational institution depended largely on social class (Houston 2002: 53). Most of the schools were in towns, and there was very little provision in the countryside (Chartier et al 1976: 6). At the most elementary level were the *petites écoles*, which taught the basics of reading, writing and arithmetic and were attended by the majority of those boys in education (Phillips 1997: 76). Even at this elementary level, Latin was the principal language: pupils would first be taught to read in Latin, and only then in French (Chartier et al 1976: 126). The main focus of the *petites écoles* was on religious teaching, as their main function was to prepare children for roles within the Church and for life as a Christian (Chartier et al 1976: 45; Léon and Roche 2008: 44).

Alongside the *petites écoles* were the *collèges*, which had begun to emerge in the middle of the fifteenth century (Brockliss 1987: 20). In the early sixteenth century, these institutions were mainly run by the universities and were of two types: the *collèges de plein exercice*, which offered a full curriculum, and the *petits collèges*, where provision was more restricted (Léon and Roche 2008: 39). The *collèges de plein exercice* provided a traditional curriculum modelled on the seven liberal arts of the mediaeval trivium and quadrivium, along with ethics and philosophy (Chartier et al 1976: 149).[39] Although the structure of educational provision remained similar to that found in the Middle Ages, the content had changed significantly. The focus was still nevertheless on the ability to speak and write in classical Latin, in either its traditional or humanist form (Chartier et al 1976: 149–50). Educational reform in the mid-sixteenth century established the colleges as the only educational establishments that could teach grammar, allowing the secondary education

[39] The trivium consisted of logic (or dialectic), grammar and rhetoric, and acted as preparation for the quadrivium, which itself consisted of arithmetic, geometry, music and astronomy (Caiazzo 2019: 180).

provided there to be clearly distinct from the elementary education offered by the *petites écoles* (Chartier et al 1976: 151).

At the same time as the colleges were growing, a decision was made to create academies for the nobility. The academies were founded because it was felt that the traditional aristocratic education of courtly arts (music, dance and good manners) and the arts of war (physical exercise, horse-riding and fencing) were no longer enough to enable the aristocracy to gain access to public offices. By the sixteenth century, the aristocracy was largely seen as ignorant and uneducated (Chartier et al 1976: 168). In order to counteract this impression, the nobility began to lose its long-standing hostility to learning, recognising the need for education as preparation for public office and participation in court life (Waquet 2001: 210). Members of the nobility who wanted their sons to have an education initially arranged for education at home but increasingly sent them to the colleges as these established their reputation (Waquet 2001: 210–11). As more members of the nobility sent their sons for education, academies were set up for them. They taught the young nobility '"bonnes lettres" et les "exercices dignes de la naissance noble"' ["learning and knowledge" and "exercises worthy of those of noble birth"] (Chartier et al 1976: 171). This consisted of a mixture of technical subjects (mathematics and its application to the art of sieges), study of government (with lessons in ethics and history), and preparation for a voyage abroad, either for diplomatic purposes or for war (modern history, geography, and languages) (Chartier et al 1976: 171).

By the seventeenth century, a number of Catholic (Jesuit and Oratorian) and Protestant colleges had been founded alongside the university-based ones. The curricula of the colleges of both denominations were very similar, based on study of ancient Greek and Latin texts and the mastery of rhetoric (Chartier et al 1976: 173). In both types of college, Latin took up the majority of the time and classical authors took up most of the curriculum (Waquet 2001: 10). The education in all of the colleges, of whichever type, was reserved for a privileged minority from the 'robe' class, whose education was designed to prepare them for university and then roles in the upper echelons of the French court (Chartier et al 1976: 173). Students who went on to university were what Laurence Brockliss describes as 'the prestigious members of the professional hierarchies of the Church, law and medicine' (1987: 5), They formed a 'small educated minority who were genuine heirs to the intellectual achievements of two thousand years of European history' (Brockliss 1987: 7). It should be noted, however, that many of the most renowned Early Modern mathematicians did not attend university, including Viète, Descartes and Pascal, the latter being educated solely at home (Eisenstein 1979: II, 537).

Education of all types was exclusive, not just university education: according to David Sturdy, enrolment information is scarce, but it is likely that only 2% of boys between the ages of eight and eighteen attended secondary education throughout the sixteenth and seventeenth centuries, although the figures may have been as high as 20% in the towns and non-existent in some rural areas (1995: 10–11). At post-secondary level, even the largest universities only had fewer than a thousand students enrolled at any one time, and the figure was significantly lower for most, particularly the provincial universities (Sturdy 1995: 4). The exclusivity of secondary and university education is reflected in seventeenth-century literacy levels. There are no statistics at all relating to literacy in France in the first half of the century. The first available data was collected retrospectively, comes from a proxy measure for literacy, the ability to provide a signature, and relates to the second half of the century: in the period 1686–90, only 21% of the population, 29% of men and 14% of women, were able to provide a signature for parish wedding registers (Van Horn Melton 2001: 82). As the ability to provide a signature is considered a reliable indicator of literacy (Van Horn Melton 2001: 82), it is reasonable to assume that the signature rate was no higher than this earlier in the seventeenth century, when there were fewer schools.

Not only was access to education restricted and literacy levels low, but the curriculum was also limited, favouring the traditional scholarly Latin curriculum as preparation for roles in the higher tiers of society. One consequence of the focus on a traditional education was that there were very few opportunities to gain a comprehensive scientific and mathematical education: while a lot of institutions taught a range of scientific subjects by the early part of the seventeenth century, very few taught mathematics in much depth (Sturdy 1995: 3). 'Natural philosophy' was taught as part of the quadrivium in the Faculty of Arts in universities, but as an abstract theoretical subject rather than as an empirical discipline, in preparation for the study of philosophy (Sturdy 1995: 5–6). The Collège Royal had been set up in 1530 with two chairs in mathematics but by the seventeenth century the level of teaching was low, despite the presence of professors of the standing of Gassendi and Roberval (Sturdy 1995: 10). At pre-university level, the Jesuit colleges had begun teaching mathematics in the second half of the sixteenth century. The mathematics taught in the colleges was both pure (arithmetic, geometry, algebra and analysis) and mixed (astronomy, optics, perspective, music, mechanics, hydraulics, fortifications, and applied geometry) (Dainville 1954: 6). After initial resistance, the usefulness of mathematics was recognised, and more specialist teachers were appointed (Dainville 1954: 8–9). The Protestant and Oratorian colleges also increasingly taught mathematics in the seventeenth century (Chartier et al 1976: 200–01). However, since mathematics was taught only as part of the two years of philosophy at the end of a school career, after classes in grammar and humanities had been completed, it only benefitted a small minority of students, the rest having left school by that stage (Chartier et al 1976: 199; Dainville 1954: 11–12). Overall, then, Sturdy is correct to conclude that '[i]n the schools, colleges and universities of France the sciences formed a relatively minor part of academic studies' (1995: 13). Despite the relative lack of time spent on mathematics overall, some impact was nevertheless felt by the small number of students who benefitted: Martin partly attributes the increase in mathematical treatises published in Paris between the 1620s and 1660s to the gradual increase in mathematics teaching in the colleges (1969: I, 544).

It can be seen from the summary of seventeenth-century education that a small but growing number of young men were emerging from their education with a good grounding in Latin and sufficient knowledge of mathematics to generate an interest in the subject. It also meant that the members of this small élite were equipped to communicate about science and mathematics with their peers across Europe (Brockliss 1987: 112). Many of these men became members of the new scientific groups and academies springing up in France, which constituted another source of audiences for mathematical texts, as will be seen in the next section.

2.3.2 The Republic of Letters and the scholarly academies

In the seventeenth century, ‘it was still essential to write in Latin when addressing a European public’ (Febvre and Martin 1976: 331). This was particularly the case for works translated into Latin, where a portion of the expected customers for published works would have been foreign readers (Pantin 2007: 164). In addition, apart from the greater ease of communication writing in Latin entailed, there was also still a sense in mathematics, that, in Pantin’s words, ‘it was difficult to be fully acknowledged and consecrated without Latin’ (2007: 170). The Latin-reading Republic of Letters had another, less obvious role too, as noted by Elizabeth Eisenstein: it enabled scholars to receive feedback from as wide a group of scholars as possible (2012: 273).

The Republic of Letters originated in Renaissance Italy in the fourteenth century as a means for educated men to participate in discussions on scholarly topics and received its name in the early fifteenth century (Fumaroli 2018: 5–7). Marc Fumaroli describes it as an ‘ideal republic’ that lasted for several centuries (2018: 9). The Republic of Letters consisted at various times of ‘academies’, based on the schools of philosophy from Antiquity, where members met to discuss literature and philosophy and had the opportunity to circulate ideas by the medium of books and letters (Fumaroli 2018: 8–9).

By the sixteenth century, the Republic of Letters had spread across Europe, and communication between members in different countries was most frequently made in Latin, its ‘language of research’ (Fumaroli 2018: 36). Cooperation between members was maintained despite a context of censorship and repression, thanks to the dual focus on correspondence and conversation and to an increasing tendency for men of letters to travel and meet each other and to maintain private libraries of scholarly books (Fumaroli 2018: 36). In Italy in the second half of the sixteenth century, the early philosophical academies had transformed themselves into artistic and scientific societies, numbering up to six hundred academic gatherings at one point (Michaux 2007: 74).

Early in the seventeenth century, ‘[t]he centre of the republic of letters shifted to France’ from Italy (Bethencourt and Egmond 2007b: 10). During this period, a number of literary *salons* and musical academies emerged, alongside ‘cabinets’ where philosophy and science were discussed (Fletcher 1996: 146).

In Roger Hahn's view, the cabinets 'were initiated to satisfy the increasing curiosity about nature's secrets' among the city's population (1971: 4). The most notable of the early Parisian cabinets was organised by the Dupuy brothers, Pierre (1582–1651) and Jacques (1591–1656); it was attended by lawyers, financiers, nobles and aristocrats, and attracted some of the finest minds of the age (Sturdy 1995: 13). It was renowned as 'a place for intellectual debate and the reception and diffusion of news' (Bethencourt and Egmond 2007b: 11). Mersenne attended the Dupuy cabinet in the late 1610s, along with Descartes and Claude Mydorge (1585–1647) (Sturdy 1995: 14). Before long, he began organising his own meetings, sharing some members with the Dupuy cabinet so that by the late 1630s his circle was made up of sixty members and included many of the leading mathematicians and scientists of the day (Sturdy 1995: 14).[40]

The role of the Parisian cabinets was threefold, according to Sturdy: they 'provided a neutral setting in which every kind of scientific idea could be discussed frankly and without reservation; [...] an invaluable forum for scholars who had no other easy access to fellow scientists or philosophers'; and a place where the sciences were treated in a systematic manner (1995: 13–14). The cabinets were forums where both traditional Aristotelianism and the newer Cartesianism could be discussed and where both had their adherents (Sturdy 1995: 22). The key consideration at this juncture is to note that the emergence of the Parisian cabinets created a small but enthusiastic audience for mathematics and science books in French or Latin, alongside a wider European audience in the Republic of Letters for books on these subjects in these languages.

2.4 Chapter conclusion

This chapter has demonstrated that, by the early seventeenth century, the dynamics of the relationship between Latin and French had evolved to a point where French had taken on many of Latin's functions, including as a language of science and mathematics. In terms of mathematical texts, the key period was between 1610 and 1665. This was a time of great innovation in mathematics in France, but not all important mathematical work was published,

[40] Mersenne's role as the convenor of a mathematical cabinet, or academy, and as a correspondent with large numbers of French and European intellectuals will be covered in chapter 4.

and much of the work that was published was ephemeral in nature. It is possible that some of the decisions not to print mathematical works were a function of the printing industry in the early seventeenth century: funding publication of a work meant either having independent means or a patron (Viala 1985: 54), while publication generally led to low sales and small returns (Martin 1969: I, 429).

Despite the constraints, a number of mathematical texts were printed in the first part of the seventeenth century, and my research has shown that, between 1610 and 1665, approximately the same number of books were printed in French as in Latin. It is clear from these findings that specialist scholars were able to choose their language of publication based on their likely audience. Four distinct but overlapping audiences for their works were identified: the Latin-reading European scholars, Latin- and French-reading French scholars, educated French-speaking non-specialists, and the increasing number of European scholars who knew French. The nature of these audiences in this period meant that scholars could also choose to produce works in both languages and be confident of an audience for both versions.

The audiences for the three case-study works were provided with a range of material: the sum of mathematical knowledge available at the time by Hérigone, a mixture of summary and innovative work on probability by Pascal, and a similar mixture of work on the mathematical basis for music by Mersenne. The historical mathematical knowledge, including bilingual terminology, mathematical symbols and signs, and methods of proof, had come down to seventeenth-century France along a variety of routes and at different times, mostly in translation. Alongside the long-established knowledge was new, innovative work developed by European mathematicians which was, in turn, generally prompted by translations, particularly from ancient Greek texts undertaken during the Renaissance. Two of the mathematicians whose work I am investigating in this thesis — Mersenne and Pascal — continued the process of mathematical innovation in the seventeenth century. All three scholars provided their work in translation by producing bilingual works, thereby enabling future mathematical innovation and continuing the role of translation in the transmission of knowledge. This account of the macro-level contextual factors surrounding the bilingual composition of Hérigone's *Cursus* *mathematicus* and *Cours mathématique*, Mersenne's *Harmonicorum libri* and *Harmonie universelle*, and Pascal's treatises on the Arithmetic Triangle has therefore shown that the historical and cultural factors that influenced their production were many and varied.

In the next three chapters, I will examine the three works in the light of these contextual factors and the micro-level factors that influenced each writer separately. In each chapter, I will begin by placing the case-study works in the context of the authors' lives and works. I will then examine the full works as self-translations, investigating the reasons for their bilingual composition and the ways in which their authors composed them, before going on to examine selected parts of the complete works in more detail.

Chapter 3

Pierre Hérigone: the *Cursus mathematicus*, or *Cours mathématique*

The six volumes of Pierre Hérigone's bilingual mathematical textbook, the *Cursus mathematicus*, or *Cours mathématique*, were first published between 1634 and 1642. The Latin and French versions of the *Cursus* were printed together on the same page in columnar and interlinear formats in each of the volumes. This *mise-en-page* immediately distinguishes the *Cursus* from the other bilingual mathematical works of the period, all of which were created and published as two separate works.[41] From a self-translation perspective, two other features of the *Cursus* stand out, in addition to its *mise-en-page*. First, as stated in the work's full title, the *Cursus* is a mathematical textbook containing mathematical demonstrations — which form one part of the text in the six volumes — presented using a clear and concise method 'sans l'usage d'aucune langue' [without the use of any language].[42] Second, the *Cursus* is not simply a mathematics textbook, but a mathematical compilation of all of the mathematical knowledge available at the time of composition (Martin 1969: I, 250). Hérigone took this mathematical material from a range of sources old and new and edited and rewrote it to compile his textbook. He credited the authors of some of the material he used, particularly where he changed little of the original work, but did not mention the origins of much of the other material.

The *Cursus* has never been studied explicitly as a bilingual text. Nevertheless, its bilingual nature raises a number of important questions that link to the fundamental questions raised in chapter 1. Why, for example, did Hérigone create the *Cursus* as a bilingual work? Where does the *Cursus* sit in relation to Hérigone's other published works? Why did he (or his publisher) decide to publish it as a single bilingual work with its dual-language *mise-en-page* rather than as two separate monolingual textbooks? What do the publishing decisions tell us about the intended audiences for the *Cursus*? And was Hérigone successful in reaching them? The three features of the *Cursus* mentioned above — the *mise-en-page*, the new, language-free method for mathematical demonstrations, and the compilation of material from a range of

[41] The full list of major bilingual mathematical works written and published between 1610 and 1665 can be found in appendix 1, section B.
[42] The work's full title is given in appendix 4.

sources — prompt further questions. Does the *mise-en-page* indicate whether either version should be considered the original? Does the addition of a wide range of symbols to replace language in demonstrations make it a trilingual work, as Descotes suggests (2006: 243)? What are the implications of the *Cursus* as a compilation of non-original material for its status as a self-translation? In other words, does the fact that Hérigone compiled the work of previous mathematicians affect his status as the work's author and therefore as its self-translator? And, finally, how similar and different are the two versions of the work and what does this show about Hérigone's practice as bilingual writer?

This case study will therefore explore Hérigone's motivations for compiling the *Cursus* as a bilingual work in its specific bilingual format, the implications of the *mise-en-page* for the relationship between the two versions of the work, and the process of compilation for Hérigone's status as a self-translator of his own work. The rest of this chapter will be split into a number of sections, focusing first on the 'what' and the 'why' of Hérigone's self-translation, before going on to examine the 'how', first at the level of the complete work and then in relation to selected parts. Section 3.1 will provide the necessary background information about Hérigone and the *Cursus* to enable detailed analysis of the work in the subsequent sections, including information about its structure and *mise-en-page*. In this initial section, I will also consider the question of original and secondary versions of the text, in the terms discussed in section 1.1. This will be followed, in section 3.2, by discussion of Hérigone's motivation for creating the *Cursus* as a bilingual Latin and French work. Section 3.3 will then look at the questions raised by Hérigone's new method and the ways in which he compiled the work. This will be followed in section 3.4 by an examination of Hérigone's self-translational practice, with a focus on the similarities and differences between the texts. I will begin this section by investigating the principal paratextual elements, before going on to study the two versions of the book on practical arithmetic in the work's second volume.

3.1 Hérigone and construction of the *Cursus*

Very little research has been conducted into Hérigone and the *Cursus*. For my knowledge and understanding of the background to both, I am particularly indebted to Per Strømholm's brief account in the *Dictionary of*

Scientific Biography, published in the early 1980s, and the more recent research conducted by Descotes and Maria Rosa Massa Esteve. Massa Esteve's research is based in the history of mathematics: it deals with Hérigone's attempts to develop a fully symbolic language for mathematical reasoning, the application of his methods to Viète's work on algebra using Euclid's *Elements*, and his influence on the work of Italian mathematicians such as Pietro Mengoli (1625–1686). Descotes's article (2006) is a general, descriptive summary of the main points of interest in the *Cursus*: its layout, the languages used in it, including symbols, its influence, and some of the mathematical works that Hérigone used in compiling the *Cursus*. Descotes also includes a discussion of Pascal's reference to Hérigone in one of the treatises accompanying the *Traité du triangle arithmétique*. Like Strømholm, both Massa Esteve and Descotes provide helpful background information about Hérigone and the *Cursus*; however, neither scholar's research deals in any detail with self-translation. Consequently their work will have little influence on my presentation of Hérigone as a self-translator.

There is agreement amongst the scholars mentioned above that little is known about Hérigone, including precisely when he was born or died (Descotes 2006: 239). He was likely to have been of Basque origin, his name probably having derived from the Basque name Hérigoyen (Descotes 2006: 239). What is known is that he spent most of his life in Paris as a teacher of mathematics and belonged to the group of mathematicians and scientists around Mersenne, the latter considering him to be a good algebraist (Descotes 2006: 239). Hérigone was clearly held in high esteem beyond his immediate circle, as, in 1634, he was appointed by Cardinal Richelieu (1585–1642), along with Mydorge, Étienne Pascal (1588–1651) and other notable mathematicians, to an official committee to judge the practicality of Morin's proposed scheme for determining longitude from the moon's motion (Strømholm 1981: 299). Although little more is known about Hérigone's life, Strømholm has no doubt that Hérigone was 'a full member of the community of French mathematicians of the first half of the seventeenth century' (1981: 299).

What little is known about Hérigone mostly involves the *Cursus*. Strømholm tells us that it was 'Hérigone's only published work of any consequence' (1981: 299). The work was dedicated to François de

Bassompierre (1579–1646), although it is not clear why, as, according to Descotes, Bassompierre's best years at the courts of kings Henri IV and Louis XIII were over and he had been imprisoned in the Bastille by Richelieu since 1631 (2006: 240).[43] It is possible that Bassompierre acted as Hérigone's patron: according to Martin, he was known to be one of the few members of the *noblesse d'épée* [the Nobility of the Sword] to be interested in books and learning (1969: I, 479). The presence of the dedication to Bassompierre in the first volume and the prefaces addressed to him in most of the other volumes suggests that this interest may well have stretched to financial support for Hérigone to publish the *Cursus*, although there is no direct evidence to support this suggestion. If Bassompierre did act as Hérigone's patron, the dedication and prefaces may possibly have been an attempt by Hérigone to help redeem Bassompierre, in addition to their traditional role as an expression of gratitude to a patron.

The first four volumes of the *Cursus* were originally published in 1634, the fifth volume in 1637 and the sixth volume, a supplement to the original five volumes, in 1642 (Massa Esteve 2008: 286). Re-bound unsold copies of the *Cursus*, with new title pages, were issued in 1644 (Massa Esteve 2008: 286; O'Connor and Robertson 2006). As can be seen in figure 1 below, the first two volumes of the *Cursus* deal with pure mathematics: volume one contains ancient Greek treatises on geometry and volume two books on practical arithmetic and algebra. The next three volumes cover mixed mathematics and its applications: volume three deals with trigonometry, practical geometry and their applications to the military and mechanics, volume four with cosmography, geography and navigation, and volume five with optics, spherical trigonometry, planetary orbits and music. In the first edition of the work, volume five is described as the fifth and final volume of the *Cursus.*[44] Volume six was originally a supplementary volume containing material on algebra, astronomy and perspective that was not included in the first five volumes, along with a

[43] The full dedication to Bassompierre describes him as 'Libero Sacri Romani Imperij Baroni, Franciæ Polemarcho Generali, Helvetiorum Rhætorumque Præfecto' [Very Distinguished Lord François of Bassompierre Marquess of Haroué, Free Baron of the Holy Roman Empire, Marshal of France, and Commander of the Swiss Rhetoricians]. According to his entry in the *Encyclopaedia Britannica*, Bassompierre was imprisoned because of his 'slight' connection to a plot to overthrow Richelieu (The Editors of Encyclopaedia Britannica 2020). Neither the *Encyclopaedia Britannica* nor any of the scholars cited in this chapter offer any evidence of any link between Bassompierre and Hérigone other than the dedication.
[44] The 1637 edition of volume five is known as the 'Tomus quintus ac ultimus' and the 'Cinquiesme et dernier tome du Cours mathematique' [Fifth and Final Volume (of the Mathematics Course)].

historical chronology.[45] While the first five volumes were published almost entirely as bilingual Latin and French texts, the majority of the sixth volume was written in French (all but the first 73 of the 267 pages in the main body of the text).

As can also be seen in figure 1, each of the six volumes of the *Cursus* is structured slightly differently, although the first five volumes are largely similar in composition.[46] The sixth volume differs significantly in structure from the other five, mostly because of an almost complete absence of paratext; by contrast, the first five volumes contain a large amount of paratext. Each of the six volumes begins with either separate title and contents pages or a single combined title and contents page; in either instance, this includes a list of the contents of the volume. In volume one, these pages are followed by three sections that do not appear in any other volume: the dedication to Bassompierre; the preface in which Hérigone addresses the reader directly, known as the 'Ad Lectorem' and 'Au Lecteur'; and three 'Prolegomena', or 'Prologomenes'.[47] In the prolegomena, Hérigone comments on a variety of topics: the different types of mathematics as understood by a seventeenth-century mathematician; how Euclid's *Elements* is divided up in volume one; and the different types of fundamental principle used in mathematics. Volumes two to five all have prefaces addressed to Bassompierre. The prefatory material occupies far more space in volume one than in any other volume, as it acts as an introduction to the whole work as well as to the first volume.[48] In volume two alone, these prefatory sections are also followed by more specific lists of the contents of the two books in the volume, dealing with practical arithmetic and algebra, each list appearing before its respective book.

[45] The twin subtitles of the 1642 edition of the sixth volume are 'Supplementum' and 'Supplement du Cours Mathematique'. In the 1644 reissue it is also known as the 'Tomus sextus ac ultimus' and the 'Tome sixiesme et dernier' [Sixth and Final Volume].
[46] I have created the table in figure 1 in such a way as to emphasise the parts in each volume that are common across the work by placing them next to each other, hence the gaps in the table. I have only included the Latin titles of sections with bilingual titles, as these come first in the text. For reasons of space, there is a fuller version of this table in appendix 4, including pagination.
[47] Throughout this chapter, once I have introduced the paratextual sections into the text, I will refer to them using the summary English descriptions set out in appendix 4.
[48] Both the dedication and the address to the reader in volume one take up four pages, while the three prolegomena take up seven and a half pages, a total of fifteen and a half pages. The preface in volume two takes up just over three pages, while the prefaces occupy just over two pages in volume three and five-and-a-half pages in volumes four and five.

<table>
<tr><th>Section</th><th>Volume 1</th><th>Volume 2</th><th>Volume 3</th><th>Volume 4</th><th>Volume 5</th><th>Volume 6</th></tr>
<tr><td rowspan="10">Paratext before main text</td><td colspan="6">Title and contents pages</td></tr>
<tr><td>Dedication</td><td>---</td><td>---</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>‘Ad Lectorem’</td><td colspan="4">‘Preface’</td><td>---</td></tr>
<tr><td>‘Prolegomena’</td><td>Contents</td><td>---</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td colspan="6">‘Explicatio notarum’</td></tr>
<tr><td>---</td><td>‘Annotationes’</td><td>---</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>---</td><td>‘Errata corrigenda’</td><td>---</td><td>---</td><td>‘Errata corrigenda’</td><td>---</td></tr>
<tr><td colspan="3">‘Explicatio citationum’ (volumes 1 and 3 only)</td><td>---</td><td>---</td><td>---</td></tr>
<tr><td>---</td><td>---</td><td colspan="2">‘Errata corrigenda’</td><td>---</td><td>---</td></tr>
<tr><td>---</td><td>---</td><td>‘Privilege du Roy’</td><td>---</td><td>‘Privilege du Roy’</td><td>---</td></tr>
<tr><td>Main text</td><td>Euclid’s *Elements* definitions and petitions; Euclid’s *Elements* and *Data*; five works by Apollonius Pergeus; Viète’s *Angularium sectionum doctrina*</td><td>‘Arithmetica Practica’; ‘Algebra’ contents; ‘Algebra’</td><td>‘Trigonometriæ’; ‘Geometriæ Practicæ’; ‘De munitione’; ‘De militia’; ‘Mechanica’</td><td>‘De sphæra mundi’; ‘Geographia’; and ‘Histiodromia’</td><td>Euclid’s *Optics*, *Catoptrics*, *Dioptrics*, *Music*; Theodosius’s *Sphærics*; ‘Perspectiva’, ‘Theoricæ Planetarum’; ‘Gnomonica’; ‘Longitude’</td><td>‘Supplementum algebræ’; ‘Isagoge de l’algebre’; ‘De la perspective’; ‘Brief traité de la theorie des planetes’; ‘Introduction en la chronologie’</td></tr>
<tr><td rowspan="6">Paratext after main text</td><td>---</td><td>‘Annotationes’</td><td>---</td><td>---</td><td>---</td><td>‘Annotations’</td></tr>
<tr><td colspan="2">‘Errata corrigenda’</td><td>---</td><td>---</td><td>---</td><td>‘Erreurs à corriger’</td></tr>
<tr><td colspan="2">‘Privilege du Roy’</td><td>---</td><td>‘Privilege du Roy’</td><td>---</td><td>---</td></tr>
<tr><td colspan="4">‘Errata’</td><td>---</td><td>---</td></tr>
<tr><td colspan="5">‘Annotationes’</td><td>‘Annotations’</td></tr>
<tr><td>---</td><td>‘Errata’/‘Annotationes’</td><td>---</td><td>---</td><td>‘Errata’</td><td>---</td></tr>
</table>

Figure 1: The structure of the six volumes of the Cursus mathematicus

In addition to the introductory material, all of the volumes contain five further sections of paratext. One is a section of notes (known as ‘Annotationes’, or ‘Annotations’); these are mainly located after the main text, although one such section in volume two can be found before the main text. All of the volumes contain ‘Errata corrigenda’, or ‘Les erreurs à corriger’ [Errata] following the main text, while volumes two, three and four also have errata before the main text, and the first five volumes also contain either a ‘Privilege du Roy’ or an extract from it.[49] While these sections of text are standard in seventeenth-century mathematical texts, the same cannot be said for the two other types of paratext. These are sections that support Hérigone’s new, language-free method for mathematical demonstrations. In each volume, the preliminary paratext is followed by the ‘Explicatio notarum’, or ‘Explication des notes’ [Explanatory table of symbols and abbreviations]. This section is where Hérigone explains the meaning of the abbreviations and symbols used in place of text in the demonstrations in the *Cursus*. Volumes one and three also contain a section entitled ‘Explicatio citationum’ or ‘Explication des citations’ [Explanatory table of references], where Hérigone gives a key to his shorthand marginal references to Euclid’s *Elements* that support the shorthand demonstrations.

An account of the structure of the *Cursus* is helpful in providing information on how the mathematical material is spread out over the six volumes, but it does not give an appreciation of the physical appearance of the *Cursus*, which is one of its most noteworthy features. Moreover, most of the research into the *Cursus* has focused on Hérigone’s new method and its use of symbols, so there has been very little examination of the layout, or *mise-en-page*, of the *Cursus* and what it tells us about the two versions of the text. As Maureen Bell has pointed out: ‘[a]ll aspects of the text’s physical form are capable of constituting meaning’, including the layout of the page (2002: 632). The text’s *mise-en-page* is therefore of critical importance: as I will demonstrate, the close proximity of the versions means that the layout is more significant than it would be for two versions printed and published as separate volumes, as it provides potential indicators about how self-translation was carried out and

[49] The *privilège du roi* system was established to provide the French crown with the power to decide what was printed and to enable publishers to make a profit by giving them a monopoly on publishing a work for a defined period of time (Viala 1985: 94).

whether either text can be considered as the original version. These are questions I will consider once I have described the *mise-en-page* in sufficient detail.

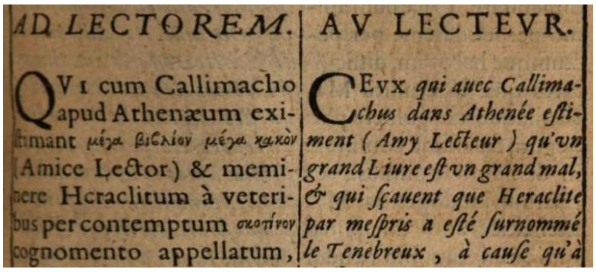
As mentioned in the introduction, the majority of the *Cursus* is set out with the text in Latin and French on the same page, though not in a single format. The comments made in relation to the *mise-en-page* by scholars investigating the work generally consist of summary remarks as part of an account of another aspect of Hérigone's work and therefore do not generally examine it in any depth. Massa Esteve is typical in saying that the work was '[p]ublished in parallel Latin and French columns on the same page' (2010: 167).[50] While Anne Coldiron finds that the columnar format is the most common layout for polyglot books (2015: 179), the overall picture in the *Cursus* is more complex. Descotes's description of the *mise-en-page* gives a more detailed and more accurate account of this complexity:

> Pour les préfaces et les introductions, le texte se présente [en] deux colonnes: à gauche le texte latin en lettres ordinaires, et à droite la traduction française en italique. Dans les traités eux-mêmes, le français et le latin sont présentés sur toute la largeur de la page, l'un après l'autre; en revanche, les démonstrations sont ensuite disposées soit sur une seule colonne, soit sur deux colonnes, mais dans un style purement symbolique.
>
> [In the prefaces and introductions, the text is presented (in) two columns: on the left the Latin text in ordinary characters, and on the right the French translation in italics. In the treatises themselves, French and Latin are displayed across the whole width of the page, one after the other; the demonstrations, on the other hand, are arranged either across a single column or in two columns, but purely using symbols] (Descotes 2006: 244).

While this description is more accurate, it still misses some of the complexity of the *mise-en-page* and does not comment on its implications. As Descotes states, there are two main types of *mise-en-page* in the volumes. Most of the paratext is presented in two columns, with the Latin text on the left, printed in roman type, and the French text on the right in italics. Although each section of paratext is slightly different from the others, this description applies in

[50] Other scholars who have commented on the *mise-en-page* in a similar way include William Shea, who states that '[a] striking feature of the work is the division of the pages into two columns, with the Latin text on one side and a French translation on the other' (2003: 241, note 1).

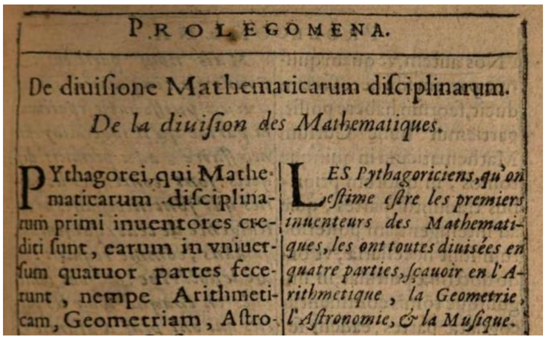
general to the address to the reader and the prolegomena in volume one, the prefaces to volumes two to five, and the notes sections in volumes one to five. Examples can be seen in figure 2.


AD LECTOREM.

QVI cum Callimacho apud Athenæum exiſtimant μέγα βιβλίον μέγα κακὸν (Amice Lector) & meminere Heraclitum à veteribus per contemptum σκοτεινὸν cognomento appellatum,

AV LECTEVR.

CEVX qui auec Callimachus dans Athenée eſtiment (Amy Lecteur) qu'vn grand Liure eſt vn grand mal, & qui ſçauent que Heraclite par meſpris a eſté ſurnommé le Tenebreux, à cauſe qu'à


PROLEGOMENA.

De diuiſione Mathematicarum diſciplinarum.

De la diuiſion des Mathematiques.

PYthagorei, qui Mathematicarum diſciplinarum primi inuentores crediti ſunt, earum in vniuerſum quatuor partes fecerunt, nempe Arithmeticam, Geometriam, Aſtro-

LES Pythagoriciens, qu'on eſtime eſtre les premiers inuenteurs des Mathematiques, les ont toutes diuiſées en quatre parties, ſçauoir en l'Arithmetique, la Geometrie, l'Aſtronomie, & la Muſique.

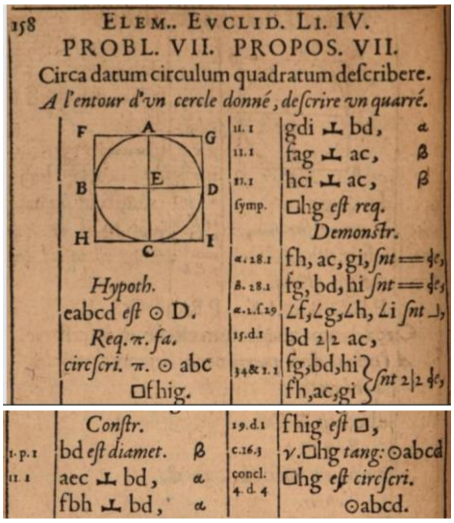
The address to the reader in volume one | The prolegomena in volume one

Figure 2: Layout in adjacent columns: the paratext in the first volume of the Cursus mathematicus

Descotes's description is less accurate in relation to the main text, however, as both types of *mise-en-page* are found in the main bilingual sections of the *Cursus*. In fact, the columnar format, which Descotes identifies as restricted to the prefaces and introductory sections, is used throughout the majority of the main text in volumes two to five and in the bilingual section at the start of the sixth volume. This format is used least in the first volume, which may be the source of Descotes's comment: it can be seen in some of the scholia and corollaries in the volume, and in the definitions and postulates sections that introduce a number of sections of the work.

The second type of *mise-en-page* identified by Descotes, an interlinear format, can also be found in the main text of all of the volumes, but, with the exception of the first volume, it occurs far less frequently than the columnar format. In this *mise-en-page*, the text in both languages is printed across the whole page. The text in Latin is written in roman type above the French text, which is again in italics. This format is most commonly found in the statement, or enunciation, in propositions, particularly in the first and third volumes, as can be seen in figure 3 below (1634e: 158; 1634h: 289). Some propositions in other volumes, however, are set out in columns. Apart from the propositions in the first and third volumes, the only sections of text that are printed across the whole page are monolingual — the dedication to Bassompierre in the first volume, the *privilèges du roi* and the majority of the sixth volume.[51]

Descotes's characterisation of the layout of the demonstrations is wholly accurate: as shown below the statement of the propositions in figure 3, they sometimes cover the entire width of the page, are sometimes set out in columns, and sometimes feature a mixture of both layouts. It is most likely that the demonstrations were set out by the printer according to the way in which they best fitted the page: diagrams and tables that required more space covered the width of the page, while symbolic and abbreviated demonstrations could most conveniently be fitted into columns. Aude Le Dividich believes that the text is 'l'exemple le plus achevé en ce qui concerne la mise en page: le texte est aéré et les différents espaces de la page sont clairement définis, permettant une lecture balisée' [the most successful example involving *mise-en-page*: the text is spaced out and the various parts of the page are clearly defined, marking out the text to be read] (2000: 342).



158 ELEM.. EVCLID. LI. IV.

PROBL. VII. PROPOS. VII.

Circa datum circulum quadratum deſcribere.

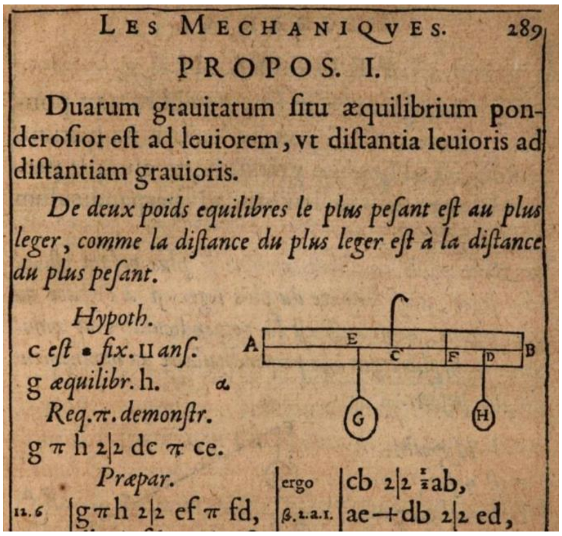
A l'entour d'vn cercle donné, deſcrire vn quarré.

Hypoth.
eabcd *eſt* ⊙ D.
Req. π. *fa.*
circſcri. π. ⊙ abc
□fhig.

Conſtr.
1.p.1 bd *eſt diamet.* β
11.1 aec ⊥ bd, α
fbh ⊥ bd, α

11.1 gdi ⊥ bd, α
11.1 fag ⊥ ac, β
11.1 hci ⊥ ac, β
ſymp. □hg *eſt req.*

Demonſtr.
α.28.1 fh, ac, gi, *ſnt* = ⫲,
β.28.1 fg, bd, hi *ſnt* = ⫲,
α.1.ſ.29 ∠f, ∠g, ∠h, ∠i *ſnt* ⊥,
15.d.1 bd 2|2 ac,
34&1.1 fg,bd,hi / fh,ac,gi } *ſnt* 2|2 ⫲,
19.d.1 fhig *eſt* □,
c.16.3 γ.□hg *tang:* ⊙abcd
concl. 4.d.4 □hg *eſt circſcri.* ⊙abcd.



LES MECHANIQVES. 289

PROPOS. I.

Duarum grauitatum ſitu æquilibrium ponderoſior eſt ad leuiorem, vt diſtantia leuioris ad diſtantiam grauioris.

De deux poids equilibres le plus peſant eſt au plus leger, comme la diſtance du plus leger eſt à la diſtance du plus peſant.

Hypoth.
c *eſt* • *fix.* ıı *anſ.*
g *æquilibr.* h. α
Req. π. *demonſtr.*
g π h 2|2 dc π ce.

Præpar.
11.6 g π h 2|2 ef π fd,

ergo cb 2|2 ½ab,
β.2.a.1. ae + db 2|2 ed,

Figure 3: Mise-en-page: text across the page, demonstrations in columns and across the page

[51] Both *mise-en-page* formats can also be found in the tables of symbols and abbreviations, tables of references, and the tables of errata found in every volume. In the various tables, the title is given in both languages, first in Latin in roman type, and then in French in italics, with the Latin title located either to the left of, or above, the French title. Within the table of symbols and abbreviations, the abbreviations are written in Latin in italics, followed by the full Latin term in roman type and the French term in italics (e.g. '*æquilat*. æquilaterum, *equilateral*' [equilateral]). In most volumes, the symbols are presented in a similar manner (e.g. 'a3, A cubus, *le cube de A*.' [a^3]). In general, this is followed by examples of how the symbols are used, in a similar format, but with the Latin text above the French ('a 2|2 b, A est æqualis B., *A est égal à B*.' [$a = b$]). The tables of references are presented in a similar manner (e.g. '15.d.1, Decima quinta definitio libri primi, *Quinziesme definition du premier livre.*' [Fifteenth definition in the first book]). The errata are presented in a table with four columns; the column headings are abbreviations given in Latin only that do not differ greatly from their French cognates, probably explaining why they are not translated (i.e. Pag., Lin., Err., Corr. [Page, Line, Error, Correction]).

The *mise-en-page* of the *Cursus* raises a number of questions. The first relates to whether either version of the text can be considered the original. In her investigation of modern bilingual editions, Hilla Karas found that the original is usually placed on the left to indicate both that it was composed first and that the reader should start reading it first (2007: 140).[52] This seems likely to be the case in any culture where text is read from left to right, as was the case in seventeenth-century Europe. However, as Gentes points out with regard to modern bilingual editions of self-translations, the conclusion that the original is placed on the left will largely depend on how the self-translation was created (2013: 273). If the versions of the text were produced consecutively, Gentes found that the original is usually found on the left (2013: 273). If, however, the two versions were created simultaneously, both can be considered as originals, irrespective of positioning (2013: 273). If Gentes's conclusions are applied to the *Cursus* and, despite the difference in publishing between the seventeenth and twenty-first century, her findings are plausible in the earlier context, there is no definitive evidence to determine which is the original version. It is nevertheless reasonable to conclude that the Latin text was placed on the left (and above the French text) either because it was the original version or because Hérigone composed the texts together but, at printing, the decision was taken to place the Latin text in its position because of Latin's historical primacy as the language of all learning, including mathematics.

The status of Latin as either the language of the original version or as the historically dominant language of learning is reinforced by its use as the sole language of the dedication and by the fonts used in the text. The two fonts — roman and italic — were almost certainly used to contrast with each other, a technique also used by Pascal in both versions of the treatise on the Arithmetic Triangle, as will be seen in chapter 5. However, by the seventeenth century, the italic font, which had initially been seen as the equal of roman type, had been 'relegated to the minor role it plays today as the latter's auxiliary' (Vervliet 2008: II, 287). Choosing the roman font for the Latin version and italics for the French version suggests that the former version was considered to be the original and more significant text in the *Cursus*. Despite the changing trends in language use

[52] Karas's findings relate to what Gentes refers to as *en face* editions, where the texts are on facing pages (2013: 266). In my view, they are also applicable to columnar and interlinear layouts, as found in the *Cursus* (2013: 275–76). It should be noted that Karas's discussion covers all types of bilingual edition, not simply self-translations, whereas Gentes focuses on self-translations alone.

in publishing that had become discernible by the 1630s, vestiges of the asymmetric relationship between Latin and French were still discernible, as evidenced by the layout of the *Cursus*.

There are two further questions raised by the *mise-en-page* of the *Cursus* that deserve attention and so will be addressed in the relevant parts of this chapter. The first question relates to its impact on the self-translator's translation decisions. In her examination of modern *en face* bilingual editions of Scottish Gaelic and English self-translated poetry, Corinna Krause discovered that the layout 'suggests a high degree of equivalence between the two texts' (2006: 2). The extent to which this observation is true of the *Cursus* will be examined in section 3.4. The second additional question raised by the layout relates to why Hérigone and the printer chose to publish the two texts in close proximity on the same page, mainly in the columnar format, but also in an interlinear format. This question will be addressed in the next section, where Hérigone's wider motivation in publishing the *Cursus* as a bilingual work with some monolingual sections will be investigated.

3.2 Why compose the *Cursus* as a bilingual work?

There were undoubtedly a number of reasons why Hérigone wrote the first five volumes of the *Cursus* and part of the sixth volume as a bilingual work, why the work was published in the columnar and interlinear formats, and why parts of it were monolingual. However, it is particularly notable that, although Hérigone uses the address to the reader in volume one to explain his new method to his readers, at no point does he indicate that the *Cursus* is bilingual. This suggests that publication of a bilingual Latin-French textbook was sufficiently common not to require comment. In fact, the only time that Hérigone mentions language at all is when he states that he intends to present his demonstrations without any languages at all.

The most significant reason for publishing the *Cursus* as a largely bilingual work was almost certainly Hérigone's personal response to the macro, society-level forces described in chapter 2: changes in the balance of Latin and French in mathematical texts, and the increase in interest in mathematical texts among non-specialists, particularly in practical, recreational and educational works. The lack of information we possess about Hérigone means that we have no insight either into his views of the two languages or the relationship between them or into his reasons for writing the *Cursus* as a bilingual work. It is likely that Hérigone simply wanted to create a mathematics course that provided the sum of all mathematical knowledge to Latin-reading experts across Europe, including France, while also being accessible to French-speaking mathematicians and amateurs. Certainly, it is Descotes's view that Hérigone wrote the *Cursus* with the two principal audiences in mind. He identifies a potential largely French-speaking audience with a range of requirements from mathematical texts. First, he believes, 'Hérigone […] s'adresse au public des personnes cultivées qui veulent […] pouvoir parler des sciences en mots propres, sans pour autant les approfondir au prix d'un temps excessif' [Hérigone (...) was addressing an audience of cultivated people who wanted (...) to be able to discuss science using the correct words without having to spend too much time delving more deeply into it] (2006: 241). This analysis is based on Hérigone's statement in the preface to the fourth volume that he has enhanced the sections on cosmography with information taken from astronomy 'pour le contentement de ceux, qui d'une part ne peuvent souffrir d'ignorer entierement les mysteres de ceste science, et de l'autre ne se veulent pas donner de la peine d'estudier jour et nuict pour s'acquerir la parfaicte intelligence d'icelle' [for the satisfaction of those who, on the one hand, cannot abide being entirely ignorant of the mysteries of this science and, on the other, do not want to take the trouble of studying day and night to acquire a perfect understanding of it] (1634i: v–vi). In the address to the reader in volume one, Hérigone describes his mathematically less expert audience as 'ceux qui sont moins advancez' [those who are less advanced] (1634b: xi). In addition, Descotes believes that Hérigone also included some material, particularly the sections on militias, troop movements, and fortifications in the fourth volume, in order to appeal to a specific part of that audience, the aristocracy (2006: 241).

The potential French-speaking audience described above would have been excluded by a work written in Latin alone (Descotes 2006: 247). In Descotes's view, Hérigone would have also been well aware of the limiting nature of a mathematical work written solely in French: 'les tentatives d'écrire les mathématiques en langue vernaculaire limitent évidemment leur écho international' [attempts to write mathematics in the vernacular limited its international reach] (2006: 247). In fact, there is plenty of evidence that both French and European mathematicians consulted the *Cursus* during the seventeenth century, though it is unclear which version of the text they read. The number of references to it shows that it was widely read at the time, including by Henry Oldenburg (*c*. 1618–1677), the first secretary of the Royal Society, John Wallis (1616–1703), John Pell (1611–1685), John Collins (*c*. 1625–1683), Isaac Barrow (1630–1677), Leibniz and Christiaan Huygens (1629–1695) in northern Europe, and Galileo, Bonaventura Cavalieri (*c*.1598–1647) and Mengoli in Italy (Massa Esteve 2006: 86, 2008: 298–99). Knowlson believes that Seth Ward (1617–1689), a mathematician and bishop of Salisbury, probably owned a copy (1975: 250, note 146). These mathematicians were all members of the Europe-wide Republic of Letters to whom the Latin version can be assumed to have been addressed. There is also a reference to Hérigone's work in one of the treatises that accompanies Pascal's *Traité du triangle arithmétique*.[53] It is not known which version Pascal read but it is likely that the work was known to the members of Mersenne's circle, as both Hérigone and Pascal were members. As such, they would have been members of the bicultural audience identified by Miglietti and discussed above (2019: 219). Evidence from remaining copies of the *Cursus* in public libraries suggests that it also had a French audience.[54]

The existence of the 'less advanced' audience does, however, provide the most plausible explanation for the decision to publish the *Cursus* as a single bilingual work. Belén Bistué notes that most mediaeval and Early Modern

---

[53] In the short treatise *Usage pour les binômes et apotomes*, Pascal describes how to use the Arithmetic Triangle to find expansions of $(x + a)^n$, but does not give a demonstration of the result, saying instead that 'Je ne donne point la demonstration de tout cela, parce que d'autres en ont déja traitté, comme Herigogne' [I am not going to demonstrate all of that as other people have dealt with it, including Hérigone] (1665d: 16). The reference was to volume two of the *Cursus,* where Hérigone created a table of numbers for finding the coefficients of integer binomial powers that was very similar in appearance to the Arithmetical Triangle (1634f: 119–24; 1634g: 17). A copy of Hérigone's diagram can be seen in appendix 2, section A.

[54] The Consortium of European Research Libraries (CERL) Heritage of the Printed Book (HPB) database (see bibliography for details) contains information from the catalogues of major European and North American research libraries for books printed between approximately 1455 and 1830. It has records relating to twenty complete or nearly complete extant collections of the *Cursus*: nine each are located in France and Germany and two in the United Kingdom. Four of the collections have a known provenance: two of the collections in French libraries and the two in the United Kingdom. Both of the French collections bear the stamps of prestigious libraries and schools: one is known to have belonged to the Collège Louis-le-Grand, founded in Paris by the Jesuits in 1563, and the other to the Abbaye Saint-Victor in Paris and the école polytechnique Palaiseau in Essonne, suggesting that the *Cursus* was used in colleges in France. One of the collections in the United Kingdom belonged to Griffin Higgs (1589–1659), the Dean of Lichfield Cathedral, who is likely to have acquired the *Cursus* soon after it was printed, leaving it to the Bodleian Library in Oxford when he died. The other collection was acquired by British mathematician Augustus de Morgan (1806–1871). This provenance information suggests that ownership outside France was more likely to involve individuals than institutions, though the small amount of information makes any conclusions no more than tentative.

bilingual texts were published for educational purposes: most were dictionaries, vocabularies, grammars, collections of proverbs and sayings, and editions of classics (2013: 97). An educational purpose would clearly reflect Hérigone's mission to bring the sum of mathematical knowledge to as wide an audience as possible in his textbook. The educational purpose described by Bistué is linguistic: teaching a second language through the presence of both source and target text in front of the reader. If Bistué's findings from a slightly earlier era are applied to the *Cursus*, it is possible to conclude that Hérigone envisaged some of his readers comparing both texts and learning how to express mathematics in both languages. Coldiron believes that some features of the multilingual columnar *mise-en-page* were specifically designed to support the use of multilingual books for instructional purposes in the ways suggested by Bistué (2015: 181). An examination of the *Cursus* demonstrates that Hérigone and his printer ensured that some of the features identified by Coldiron were in place to support the reader, particularly the clear separation of columns of print and the spacing of text within them, which, as can be seen in many of the figures in this chapter, are evident in the way the two versions of the text of the *Cursus* are placed in separate boxes and the manner in which the boxes are spaced to ensure that the same material can be found in approximately the same place in the two versions. In addition, Coldiron has found that the interlinear format also found in the *Cursus* was designed to promote engagement with the bilingual text and prevent the reader from monolingual reading (2015: 181). Coldiron's findings as they relate to both *mise-en-page* formats clearly apply to the *Cursus*. This supports the hypothesis of an educational purpose for the *Cursus*, a theory that seems all the more credible when other factors noted above are taken into consideration. In particular, Hérigone was a teacher of mathematics with an interest in language: his focus on simplicity and clarity of style and his creation of an etymological dictionary of mathematical terms are clear indications of a fascination with language and learning that make an educational purpose for the *Cursus* highly likely.

However persuasive the analysis provided above of Hérigone's motives for writing the *Cursus* as a largely bilingual work, it does ignore the fact that parts of the work were written in just one or other of the languages. These sections are very much the minority of the work; they nevertheless account for a sufficiently large proportion of the complete work to require attention. Some of the monolingual sections are relatively short. Such is the case, for example, with the four-page dedication to Bassompierre in volume one, which is printed solely in Latin. As with most dedications, the text is almost wholly given over to the standard rhetorical practice of praising the dedicatee. He is described as ‘primum inter mortales’ [first amongst mortals] of whom the work is not worthy: ‘tua vero fama sublimior est quam ut hæc minuta donaria respiciat’ [your truly great reputation is loftier than this treasure that it gazes upon] (Hérigone 1634a: vi). The sole use of Latin is likely to have been partly for reasons of flattery: Hérigone was implicitly telling Bassompierre that he knew that Bassompierre was well educated in the higher prestige language and therefore in no need of the French translation. Apart from a page of propositions preceding Euclid’s *Optics* in volume five, this is the only part of the *Cursus* published entirely in Latin. The reason may be related to Miglietti’s observation regarding the reduction in paratext in Mizauld’s self-translations as he adapted them for a non-Latin-reading audience: any item of paratext that stressed the scholarly nature of the work was removed (2019: 221). In Hérigone’s case, this meant not over-promoting Latin as the language of mathematics in the paratext.

The most significant section of text that was written solely in French is the majority of the sixth volume: all but the ‘Supplementum Algebræ’, or ‘Supplement de l’Algebre’ [Algebraic Supplement], which takes up just 73 of the 267 pages of main text and is mainly set out in the same bilingual columnar format as found elsewhere in the work. The only other published work attributed to Hérigone was also printed entirely in French: this was *Les six premiers livres des Éléments d’Euclide* [The First Six Books of Euclid’s *Elements*], a 468-page single-volume work published in 1639, between the fifth and sixth volumes of the *Cursus*. This work uses the French text and symbols from the first volume of the *Cursus*, and also includes a *Brief traicté de l’Arithmetique Practicque* [Brief Treatise on Practical Arithmetic] that summarises much of the French text of the book on practical arithmetic from the second volume of the *Cursus*, chapters on trigonometry, practical geometry, fortifications, and gnomonics, taken from various volumes in the *Cursus*, and an etymological dictionary of French mathematical terms. The dictionary seems to be the only original material in the volume. A decision appears to have been made to dispense with the Latin text for what is, to all intents and purposes, an abridged version of the *Cursus*, published after the original five volumes but before the supplementary volume.

It is possible that the decision to publish the abridged volume in French between the first five volumes and the final volume of the *Cursus* was influenced by the same trends in French publishing in the 1620s and 1630s that were highlighted in section 2.1.3: the number of mathematical books published in French in these two decades exceeded the number in Latin, particularly practical and educational works. It may have been the case that *Les six premiers livres* was successful as a French-only volume aimed at the audience for books of these types: its smaller size (as an abridged text in one language only) would have meant that it was cheaper to produce and to purchase and less intimidating for a non-specialist audience. It is therefore also possible that, when the sixth volume was published, Hérigone and his publisher decided that an audience would be guaranteed by publishing a shorter, cheaper work solely in French.

The lack of primary evidence makes it difficult to draw definite conclusions about Hérigone's motives for publishing the *Cursus* as a largely bilingual work with a sixth volume mostly in French. However, the macro forces at play in publishing in the 1620s and 1630s give credibility to the conjectures made above: changing trends meant that mathematical works either in both languages or in French alone became increasingly viable and acceptable during the period in question. The next section will move from consideration of the 'why' of publishing the *Cursus* in the format in which it appeared to the 'how', and the implications of two of Hérigone's decisions in creating the *Cursus* for its status as a self-translation or bilingual work: the introduction of a new 'language-free' method for presenting mathematical demonstrations and the process of compiling largely non-original material.

3.3 Composing the *Cursus* as a bilingual work

3.3.1 Hérigone's 'new way' of presenting mathematics

When it was first published, the *Cursus* was particularly known for what Strømholm has characterised as 'the introduction of a complete system of mathematical and logical notation' (1981: 299).[55] As such, it can be seen as the successor of the sixteenth-century advances in algebra (Massa Esteve 2012: 154). In the context of self-translation, Hérigone's introduction of symbols to the *Cursus* was important because he saw it as a way of dispensing with the other two languages in his mathematical demonstrations, while potentially introducing a third language. In this subsection, I will outline Hérigone's method, largely in his own words, before going on to investigate the implications for the status of the *Cursus* as a bilingual work.

In the dedication to Bassompierre in the first volume of the *Cursus*, Hérigone characterises his new method in the following manner: 'Viam novam ingressus perfeci quod nullus tentaverat in scientia vastissimi ambitus, et per multa volumina dissipata' [I have perfected a new approach that no one has tried in science on such a large scale, and spread it across a number of volumes] (1634a: vi–vii). Hérigone explains the rationale for his new method in the following terms:

> [C]eux qui entreprennent de mettre des Livres en lumiere, doivent bien prendre garde à deux choses; à sçavoir qu'il ne se trouve en leurs escrits rien de superflu, qui apporte du dégoust, ny rien de difficile et obscur, qui rebute le Lecteur.
>
> [Those who undertake to bring Books into existence should be very careful of two things; namely, that they include nothing superfluous in their writings, which would be distasteful, nor anything difficult or obscure, which would dishearten the reader] (1634b: ix).[56]

Hérigone's intention in writing the *Cursus* was therefore to banish extraneous and opaque material and demonstrate the mathematical ideas, processes and examples in as clear a style as possible:

> on ne doute point, que la meilleure methode d'enseigner les sciences est celle, en laquelle la briefveté se trouve conjoincte avec la facilité: mais il n'est pas aisé de pouvoir obtenir l'une et l'autre, principalement aux Mathematiques, lesquelles comme tesmoigne Ciceron, sont grandement obscures.

[55] Examples of how the symbols are presented in the *Cursu*s can be seen in most of the figures in this chapter, particularly in section 3.1, where the *mise-en-page* of the work is explored.
[56] The passages of text cited in this section also appear in the Latin version of the address to the reader; as the French and Latin texts are not being compared with each other, but are simply being used for illustrative purposes, they have been provided in French only.

> [there is no doubt that the best method for teaching the sciences is to combine conciseness and simplicity: but it is not easy to achieve either, particularly in Mathematics, which, as Cicero testifies, is largely opaque] (1634b: ix–xi).[57]

Hérigone's solution to the opacity of mathematical language is to introduce his own concise, easily comprehensible symbolic system: 'j'ay inventé une nouvelle methode de faire les demonstrations, briefve et intelligible, sans l'usage d'aucune langue' [I have invented a new method of creating demonstrations that is concise and intelligible without using any language] (1634b: x).[58] Where previous mathematicians relied on a word-based approach to demonstrating mathematical ideas, one aspect of Hérigone's new method is to replace this with concise demonstrations using symbols, abbreviations and references to form a kind of universal language that any reader can understand. The aim is for the method to be applicable to any area of mathematics, as seen throughout the *Cursus* (Le Dividich 2000: 342).[59]

The other feature of Hérigone's new method is improvements to the quality of mathematical demonstrations: in Hérigone's opinion, the difficulty in understanding demonstrations comes from poor explanations that frequently lack definitions of terminology and axioms. Unlike other contemporary books, Hérigone's text will not affirm anything that has not already been confirmed, using his references, and will not use words or axioms that have not previously been defined for the reader. This desire for rigour in the use of definitions and

---

57 The reference to Cicero relates to *De oratore* [On the Orator], where the author asks 'Quis ignorat, ei, qui mathematici vocantur, quanta in obscuritate rerum, et quam recondita in arte, et multiplici subtilique versentur?' [Who does not know, as regards the so-called mathematicians, what very obscure subjects, and how abstruse, manifold, and exact an art they are engaged in?] (1942: I, 10).

58 This is the 'brief and clear new method' in the work's full title. This was not a new idea: Fabio Bertato states that, in the sixteenth century, Clavius had argued 'in favor of brevity and ease' of understanding in much the same way as Hérigone (2018: 126). Cifoletti also notes that, in a discussion about a long-standing debate concerning the best way of presenting mathematics, Peletier, in his *Arithmetique* (1549), emphasises the desirability of clarity and concision (1992: 250). All three writers were promoting 'the ancient ideals of linguistic simplicity and transparency', or 'perspicuitas', in opposition to 'obscuritas' (Skouen and Stark 2015b: 38; Nate 2015: 84). The same rhetorical goal of persuading the reader that a text can be considered 'scientific' if written in a 'plain style' can be seen in the early Royal Society's discussions about presentational style later in the seventeenth century (Skouen and Stark 2015b: 38; Nate 2015: 78). Tina Skouen and Ryan Stark's sourcebook (2015a) is part of recent research into seventeenth-century discussions of clear and concise scientific writing. Hérigone's own rhetorical use of 'perspicuitas' and 'brevitas' is discussed in section 3.4.1 below.

59 In Hérigone's own time, Descartes wrote in his unpublished *Regulæ ad directionem ingenii* that 'Quæ vero præsentem mentis attentionem non requirunt, etiamsi ad conclusionem necessaria sint, illa melius est per brevissimas notas designare quam per integras figuras' [As for things which do not require the immediate attention of the mind, however necessary they may be for the conclusion, it is better to represent them by very concise symbols rather than by complete figures] (1998: 196). As Le Dividich notes, there are strong similarities between the approaches advocated by Descartes and Hérigone (2000: 345–46).

demonstrations can also be seen in Pascal's method, as set out in *De l'esprit géométrique*, and discussed in chapter 5.

Each one of Hérigone's propositions will therefore follow the traditional Greek principles of deductive reasoning, in a logical order, thereby facilitating understanding: '[l]a distinction de la proposition en ses membres, sçavoir en l'hypothese, l'explication du requis, la construction, ou preparation, et la demonstration, soulage aussi la memoire, et sert grandement à l'intelligence de la demonstration' [the separation of the proposition into its constituent parts, namely the hypothesis, the explanation of the unknown, the construction, or preparation, and the demonstration, all soothe the memory and help greatly in understanding the demonstration] (1634b: xii). This follows the order established by Proclus in his commentary on the *Elements*.[60] The significant difference in Hérigone's new method is the use of symbols instead of words in the logical steps through the proposition. An example of Hérigone's method can be seen in figure 4 below: this is the first proposition in the first book of the *Elements*, which Hérigone mentions in the address to the reader (1634e: 158).[61]

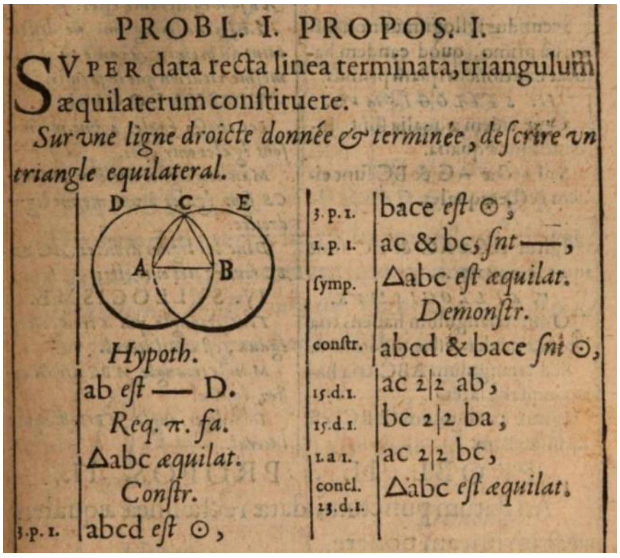
Despite his determination to change the nature of mathematical demonstrations, Hérigone's concept of a fully symbolic replacement for mathematical text was not fully realised and did not have a lasting impact. As figure 4 demonstrates, Hérigone needed some Latin and French vocabulary, mathematical terminology in particular, to make the symbols fully comprehensible. Moreover, very few of his symbols have survived into modern mathematics: the symbol ⊥ to signify 'is perpendicular to' is his most significant contribution (Cajori 1993: 408). That is not to say that there was no enthusiasm for his system in the seventeenth century: as Florian Cajori has noted,

---

[60] A brief account of Proclus's analysis of Euclid's demonstrations can be found in section 2.2.2. Clavius refers to Proclus's commentary in both the preface and prolegomena to his Latin translation of the *Elements* which, as will be seen in section 3.3.2 below, was the source for Hérigone's Latin version of the *Elements*. Although Hérigone does not mention Proclus in his prolegomena, he was clearly well aware of his importance in analysing the demonstrations: he notes in volume six of the *Cursus* that Proclus 'a escrit des Commentaires tres-doctes sur les Elem. D'Euclide' [wrote very learned *Commentaries* on Euclid's *Elements*] (1642b: 224).

[61] In this example, the proposition begins with a statement (the problem of drawing an equilateral triangle from a straight line) and a diagram of the triangle. The working begins with the hypothesis (*Hypoth*.), that AB is a straight line, and the statement of what is required (*Req*.), i.e. for triangle ABC to be equilateral. This is followed by the preparatory work, including marginal references to postulates from the beginning of the *Elements* (3.p.1, etc.) and the demonstration (*Demonstr.*), again supported by marginal references, this time to definitions and axioms from the beginning of the *Elements* (15.d.1, 1.a.1 etc.). The proposition finishes with the conclusion (concl.) that what was required to be demonstrated has been demonstrated.

‘Hérigone’s symbolism found favor with some writers’ in a number of parts of Europe (1993: 347).


PROBL. I. PROPOS. I.

SVPER data recta linea terminata, triangulum æquilaterum constituere.

Sur vne ligne droicte donnée & terminée, descrire vn triangle equilateral.

D C E
A B

Hypoth.
ab *est* — D.
Req. π. *fa.*
△abc *æquilat.*
Constr.
3.p.1. abcd *est* ⊙,

3.p.1. bace *est* ⊙;
1.p.1. ac & bc, *snt* —,
symp. △abc *est æquilat.*
Demonstr.
constr. abcd & bace *snt* ⊙,
15.d.1. ac 2|2 ab,
15.d.1. bc 2|2 ba,
1.a.1. ac 2|2 bc,
concl. 23.d.1. △abc *est æquilat.*

Figure 4: Hérigone’s demonstration of the first proposition in the first book of Euclid’s Elements *using his new method*

From a self-translation perspective, Hérigone’s desire to create ‘language-free’ demonstrations using his symbols adds another potential language to the *Cursus*, causing Descotes to wonder whether it can be considered a trilingual work rather than a bilingual one (2006: 243). Montgomery provides a seemingly straightforward answer: although ‘[e]quations, formulas, propositions, measurements, and alphanumerical or geometrical expressions of all kinds’ are found in written explanations and discussions in all mathematical writing, ‘as yet, mathematical articulation does not approach a fully self-sufficient system of communication’ (2000: 254). The restricted use of the symbols and their inability to form a separate communication system means that the work as a whole cannot be considered as trilingual; it can, however, be viewed as a work with translingual elements. The nature of some of the abbreviations Hérigone uses and the close relationship between Latin and French mean that, in some instances, there is a merging of the two languages in his demonstrations: this is the case, for example, with the use of ‘snt’ for both ‘sont’ and ‘sunt’, ‘concl.’ for both ‘conclusio’ and ‘conclusion’, amongst other abbreviations, as can be seen in figure 4 and elsewhere in the *Cursus*. Overall, the *Cursus* can be said to be a largely bilingual work with demonstrations provided using a highly personalised system that largely dispenses with standard written language.

3.3.2 Compiling the *Cursus*

In creating his compilation, Hérigone made no claims about the originality of any of the mathematics included in it. Descotes states that Hérigone took great care to name the mathematicians whose work he was collecting and compiling, often without making significant changes to the original text (2006: 241). While this may have been true for much of the material, it can be shown that, in some cases, Hérigone took mathematical material from his sources without attribution. However, as will be shown below, irrespective of the source of the mathematical material, his approach was to make changes to the material he used, the degree of change varying from source to source, while ensuring that the two versions of the *Cursus* corresponded closely. The question at issue for self-translation is whether this use of other mathematicians' work, whether attributed or not, and the degree to which he adapted it, has an impact on Hérigone's status as the author of the *Cursus* and the status of the *Cursus* as a self-translated work.

As can be seen in figure 1, the first volume in the *Cursus* consists of the fifteen books of Euclid's *Elements*, including the two apocryphal ones; it also includes Euclid's *Data*, Apollonius's *Conics*, as reconstituted in Latin by contemporary mathematicians such as Viète, Snel and Ghetaldi, and Viète's *Ad angularium sectionum doctrina* [On Analysis of Angular Sections] (1615).[62] All of the works used in this volume are acknowledged by Hérigone. In addition, the fifth volume of the *Cursus* includes Euclid's treatises on optics, catoptrics, dioptrics and music, and Theodosius's treatise on spherical geometry, all of which are attributed. The book on algebra in Hérigone's second volume presents Viète's work on algebra, which Hérigone again acknowledges, this time in the contents section preceding the book, where he states that 'la plus-part [...] ont esté pris de divers traitez de Viette' [the majority (...) have been taken from various treatises by Viète] (1634g: xvi). Finally, the sixth volume includes an example using Fermat's method for finding maxima and minima

[62] In the *Cursus*, Viète's work is known as the *Angularium sectionum doctrina*, or *La Doctrine de la section des angles* [The Doctrine of Angular Sections].

applied to the tangent to a parabola that is credited to ‘son inventeur’ [its inventor] (1642a: 68).

While all of the mathematicians mentioned above have their work directly recognised by Hérigone, this is not the case for other notable scholars whose work he used. Pierre Duhem has noted the unattributed influence of the work of a number of mathematicians on Hérigone’s chapter on mechanics in the third volume of the *Cursus*, including Stevin, Guidobaldo del Monte (1545–1607), and Jordanus de Nemore (*fl. c.* 1220) (2012: 208, 213).[63] Hérigone does acknowledge Guidobaldo and Stevin’s contribution to mechanics in his ‘Introduction en la chronologie’ [Introduction to Chronology] in the sixth volume, but does not explicitly acknowledge his use of any of their work (1642b: 239–40). Kristi Andersen has also highlighted Hérigone’s use of Stevin’s work as an inspiration for his ‘thorough treatment of perspective’ in the fifth and sixth volumes (2007: 288, 404–06), while Eberhard Knobloch has observed that, in the second volume, Hérigone undoubtedly ‘based his combinatorial explanations particularly on Clavius’ (2013: 141), a view supported by Ernest Coumet (2019: 295–300). These are just a few cases where interested scholars have noted Hérigone’s sources. There are undoubtedly others yet to be uncovered; identifying them would enable scholars to investigate the degree to which Hérigone has rewritten his source material for inclusion in the *Cursus*. Before investigating Hérigone’s use of his source material in more detail, it should, however, be noted that Alain Lieury believes that the chapter entitled ‘De l’arithmétique mémoriale’ [Arithmetic for Memorisation] in the book on practical arithmetic in the second volume contains original material: Hérigone’s own invention of a letter-number code technique for memorising complex numbers, such as dates, by transforming them into simple words or pseudo-words (2013: 64–66).[64] The words created using Hérigone’s system do not themselves belong to any known language, being simply intended to be easy to

[63] Duhem does, however, believe that publication of the *Cursus* ‘made a great contribution by publishing the most important discoveries made by Stevin in physics’ that would not otherwise have been known (2012: 214–15).

[64] Hérigone’s interest in a letter-number code as a mnemonic and the inclusion of a chapter on the subject in the *Cursus* provide another indication of his fascination with language and learning, as well as with mathematics, as discussed in section 3.2 above.

pronounce and remember.[65] Not quite all of the material in the *Cursus* is therefore taken from other sources.

The breadth of mathematics collected in the *Cursus* raises the question touched on in section 1.4 regarding collaborative practices in the Early Modern period: was Hérigone solely responsible for creating the *Cursus*? As has already been noted, very little is known about Hérigone's life or work; this lack of knowledge makes it impossible to arrive at definitive conclusions regarding his working practices. However, Blair makes the reasonable point that printed compilations would not usually have been conceivable without the contribution of more than one author (2010: 174). It is therefore likely that Hérigone was not the sole author of the *Cursus*. Any conclusions about Hérigone's decision-making in the *Cursus*, whether directly or indirectly related to self-translation, should be read with the possibility in mind that Hérigone was not the work's only author.

The impact of Hérigone's use of non-original material in compiling the *Cursus* on his status as the author, whether sole or joint, and on the work's status as a self-translation can best be seen by examining two of the sources most frequently cited in this context by scholars: Clavius's Latin version of Euclid's *Elements* (1591 edition) and Snel's Latin translation of Stevin's *Van de weeghconst*, known in Latin as the *Liber de staticæ elementis* [Book on the Elements of Statics] (1605). These are both sources where Descotes believes that Hérigone introduces the fewest changes either to the Latin texts or the French translations of the Latin texts, both only published in the first third of the seventeenth century: Henrion's *Les quinze livres des Elements geometriques d'Euclide* [The Fifteen Books of Euclid's *Elements*] and Girard's *L'art pondéraire, ou La statique* respectively (2006: 243).[66]

There can be no doubt that Hérigone's Latin text of the *Elements* is based on Clavius's version: he states in the third prolegomenon in the first volume of the *Cursus* that Clavius's text is 'la version et ordre duquel nous

[65] Hérigone gives the example of the year 1632, which is transformed into '*parce, prace, et afice*' (1634f: 137).
[66] It should be noted that the French translations are not translations of Euclid's original Greek and Stevin's original Dutch work, but of the Latin versions of the original texts produced by Clavius and Snel respectively.

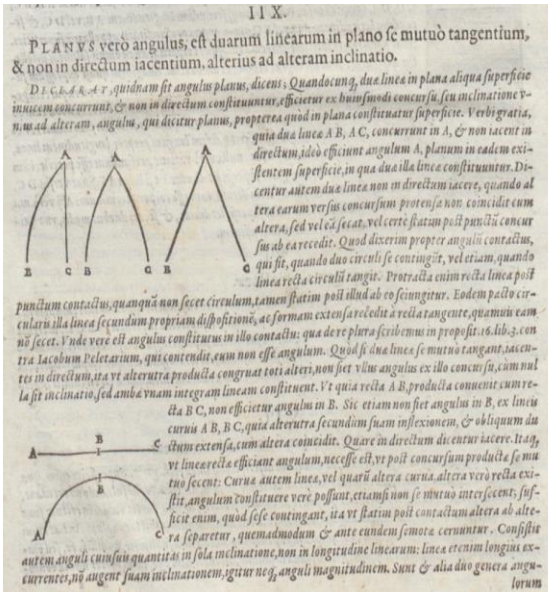
avons suivi' [the version and order we have followed] (1634c: xx).[67] Descotes believes that Hérigone chose Clavius's version because, at the time, it was considered to be one of the more successful, enabling Hérigone to make use of both Clavius's text and Henrion's French translation of it without introducing many changes (2006: 243). Close textual examination shows that Hérigone did not copy all sections of Clavius's and Henrion's texts, but that the similarities between the sections in the *Cursus* and Clavius's and Henrion's texts vary depending on the sections' function within the text. There are, for example, strong similarities between Hérigone's and Clavius's prolegomena.[68] The remaining similarities are in the definitions, axioms, postulates and propositions that structure the rest of the work. Even in these sections, however, Hérigone does not simply copy the entire text from Clavius or Henrion, though he does ensure that his own two versions of the texts correspond closely. This can be seen, for example, in Hérigone's definitions: while he uses all of Clavius's text for the statement of the definitions, he frequently deviates from Henrion's text. Hérigone's commentaries on the definitions are also generally shorter than either Clavius's or Henrion's. His practice can be seen in definition VIII in book 1, as shown in figure 5 below: Hérigone edits Clavius's and Henrion's commentaries, dispenses with the diagrams, and uses some of their phrases to

[67] Hérigone largely uses Clavius's structure for the *Elements*, but with some minor changes. He adds a definition in book 5, but omits one in book 6 and three in book 7, and adds a postulate and rewrites two axioms in book 7. In addition, he adds an appendix to book 6. It is only towards the end of the *Elements* that there are many differences in the content of the two versions: in book 14, Hérigone only includes eight of Clavius's thirty-two propositions, and in book 15 includes only the first five of Clavius's twenty-one. The basis for Hérigone's decision to include little of these two books was probably his knowledge that they were not written by Euclid: book 14 was composed by Hypsicles of Alexandria (*fl*. first half of second century BCE), and book 15 by a pupil of Isidorus of Miletus (*fl*. sixth century) (Bulmer-Thomas 1981a: 415, 433; 1981b: 616; 1981c: 29). Clavius also includes a sixteenth book that does not appear in either Hérigone's or Henrion's versions. Hérigone also adds his own scholia to some of Clavius's versions of the propositions to justify some of his own demonstrations (Massa Esteve 2010: 176). Clavius himself acknowledged adding 671 propositions to Euclid's original 486 (Murdoch 1981: 451)

[68] Hérigone uses some of Clavius's prolegomena as the basis for his own. Clavius's version of the *Elements* includes eight prolegomena (none of which are included in Henrion's translation), while Hérigone's *Elements* only has three, in both Latin and French, based on Clavius's first, sixth and eighth prolegomena. The Latin versions themselves are not direct copies of all of Clavius's text, although Hérigone does copy some sections. Like Clavius, Hérigone begins his first prolegomenon with a discussion of how the Pythagoreans divided mathematics into four parts: arithmetic, geometry, astronomy, and music. However, Clavius has the four parts of mathematics in a different order. Overall, Clavius's text is much longer, but the general subject matter of the two prolegomena is similar: they both discuss the separation of mathematical subject areas into pure and mixed mathematics, though they name different mixed subjects. Hérigone's second prolegomenon is taken directly from the end of Clavius's sixth prolegomenon; only the punctuation is different. Much of the text of Hérigone's third prolegomenon is also taken directly from Clavius's text, though in this case it is edited rather than copied, and then translated into French. Both authors discuss the three principles of mathematics that form the basis of all mathematics and which do not require proof: definitions, postulates and axioms. Clavius attributes the insistence on these principles to Aristotle and Proclus, whereas Hérigone omits that part of the text.

create shorter summary versions, all the time ensuring that the two versions of his own text correspond as exactly as possible.

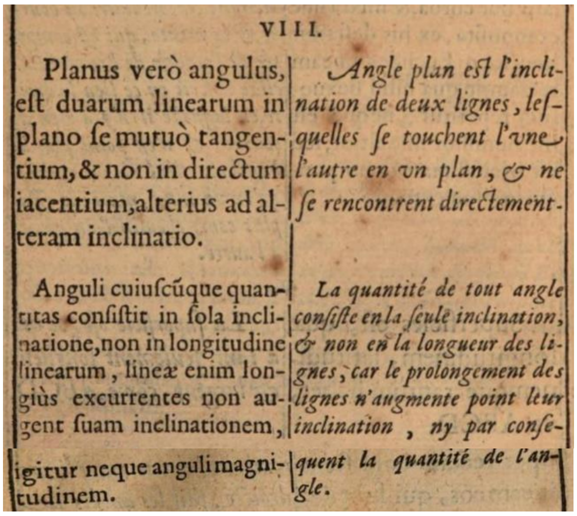
Clavius (in Euclid 1591: 4)


IIX.

PLANVS verò angulus, eſt duarum linearum in plano ſe mutuò tangentium, & non in directum iacentium, alterius ad alteram inclinatio.

DECLARAT, quidnam ſit angulus planus, dicens; Quandocunq; duæ lineæ in plana aliqua ſuperficie inuicem concurrunt, & non in directum conſtituuntur, efficietur ex huiuſmodi concurſu, ſeu inclinatione vnius ad alteram, angulus, qui dicitur planus, propterea quòd in plana conſtituatur ſuperficie. Verbi gratia, quia duæ lineæ A B, A C, concurrunt in A, & non iacent in directum, ideò efficiunt angulum A, planum in eadem exiſtentem ſuperficie, in qua duæ illæ lineæ conſtituuntur. Dicentur autem duæ lineæ non in directum iacere, quando altera earum verſus concurſum protenſa non coincidit cum altera, ſed vel eã ſecat, vel certè ſtatim poſt punctũ concurſus ab ea recedit. Quod dixerim propter angulũ contactus, qui fit, quando duo circuli ſe contingũt, vel etiam, quando linea recta circulũ tangit. Protracta enim recta linea poſt punctum contactus, quanquã non ſecet circulum, tamen ſtatim poſt illud ab eo ſeiungitur. Eodem pacto circularis illa linea ſecundum propriam diſpoſitionẽ, ac formam extenſa recedit à recta tangente, quamuis eam nõ ſecet. Vnde verè eſt angulus conſtitutus in illo contactu: quà de re plura ſcribemus in propoſit. 16. lib. 3. contra Iacobum Peletarium, qui contendit, eum non eſſe angulum. Quòd ſi duæ lineæ ſe mutuò tangant, iacentes in directum, ita vt alterutra producta congruat toti alteri, non fiet vllus angulus ex illo concurſu, cùm nulla ſit inclinatio, ſed ambæ vnam integram lineam conſtituent. Vt quia recta A B, producta conuenit cum recta B C, non efficietur angulus in B. Sic etiam non fiet angulus in B, ex lineis curuis A B, B C, quia alterutra ſecundùm ſuam inflexionem, & obliquum ductum extenſa, cum altera coincidit. Quare in directum dicentur iacere. Itaq; vt lineæ rectæ efficiant angulum, neceſſe eſt, vt poſt concurſum productæ ſe mutuò ſecent: Curuæ autem lineæ, vel quarũ altera curua, altera verò recta exiſtit, angulum conſtituere verè poſſunt, etiamſi non ſe mutuò interſecent; ſufficit enim, quòd ſeſe contingant, ita vt ſtatim poſt contactum altera ab altera ſeparetur, quemadmodum & ante eundem ſemotæ cernuntur. Conſiſtit autem anguli cuiuſuis quantitas in ſola inclinatione, non in longitudine linearum: lineæ etenim longius excurrentes, nõ augent ſuam inclinationem, igitur neq; anguli magnitudinem. Sunt & alia duo genera angulorum

Hérigone (1634d: xxxvi)


VIII.

Planus verò angulus, eſt duarum linearum in plano ſe mutuò tangentium, & non in directum iacentium, alterius ad alteram inclinatio.	Angle plan eſt l'inclination de deux lignes, leſquelles ſe touchent l'vne l'autre en vn plan, & ne ſe rencontrent directement.
Anguli cuiuſcũque quantitas conſiſtit in ſola inclinatione, non in longitudine linearum, lineæ enim longiùs excurrentes non augent ſuam inclinationem, igitur neque anguli magnitudinem.	La quantité de tout angle conſiſte en la ſeule inclination, & non en la longueur des lignes, car le prolongement des lignes n'augmente point leur inclination, ny par conſequent la quantité de l'angle.

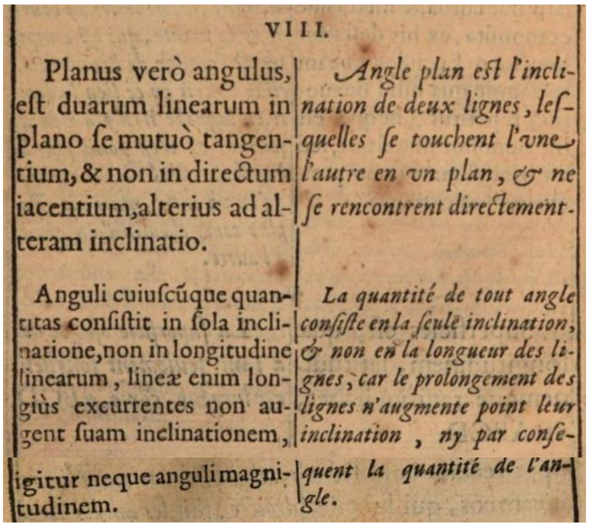
Henrion (in Euclid 1632: 5)


8. Angle plan, eſt l'inclination de deux lignes, l'vne à l'autre ſe touchant en vn plan non directement.

Euclide enſeigne icy que quand deux lignes conſtituees en quelque ſuperficie plane concurrent en vn poinct d'icelle ſuperficie, & ne ſe rencontrent directement, alors l'inclination d'icelles deux lignes s'appelle angle plan. Comme par exemple, pour ce que les deux lignes A B, & A C, concurrent en A, & ne ſe rencontrent pas directement; le concours ou inclination qu'icelles deux lignes font au poinct A, s'appelle angle: Et d'autant qu'iceluy angle eſt conſtitué au meſme plan qu'icelles deux lignes A B & A C, on l'appelle angle plan, à la difference d'autres angles, dont les vns ſont nommez angles ſolides, deſquels traicte cy apres Euclide en la Stereometrie; & les autres ſont appellés angles ſpheriques, deſquels traictent amplement Menelaus & Theodoſe en leurs elemens ſpheriques, comme nous auons auſſi faict en nos triangles ſpheriques.

Or quant à l'angle plan cy-deſſus deffiny eſt à remarquer, premierement que la grandeur ou quantité dudit angle plan conſiſte en la ſeule inclination des lignes qui le conſtituent, & non pas en la longueur d'icelles lignes; car le prolongement deſdites lignes n'augmente point leur inclination, ny par conſequent la grandeur de l'angle. En apres que quelques Geometres ont

Hérigone (1634d: xxxvi)


VIII.

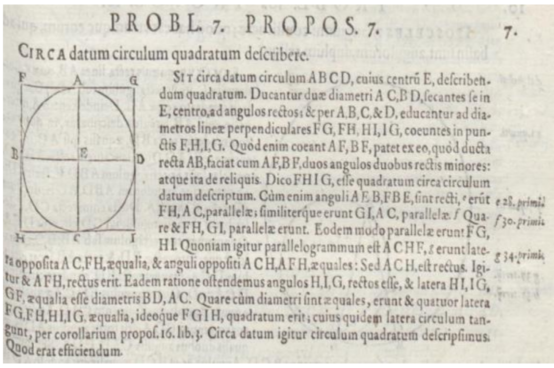
Planus verò angulus, eſt duarum linearum in plano ſe mutuò tangentium, & non in directum iacentium, alterius ad alteram inclinatio.	Angle plan eſt l'inclination de deux lignes, leſquelles ſe touchent l'vne l'autre en vn plan, & ne ſe rencontrent directement.
Anguli cuiuſcũque quantitas conſiſtit in ſola inclinatione, non in longitudine linearum, lineæ enim longiùs excurrentes non augent ſuam inclinationem, igitur neque anguli magnitudinem.	La quantité de tout angle conſiſte en la ſeule inclination, & non en la longueur des lignes, car le prolongement des lignes n'augmente point leur inclination, ny par conſequent la quantité de l'angle.

Figure 5: Euclid's Elements*, book 1, definition 8*

Because of Hérigone's 'new method' of providing demonstrations of propositions, there is a greater difference between the texts of the propositions that make up the majority of the *Elements* than the text of the definitions. As with the definitions, Hérigone uses Clavius's and Henrion's initial statements, again ensuring they correspond in the two versions of his own text, but

Clavius's and Henrion's verbal explanations are replaced by Hérigone's symbolic demonstrations. Figure 6 below shows a typical example.

Clavius (Euclid 1591: 179)



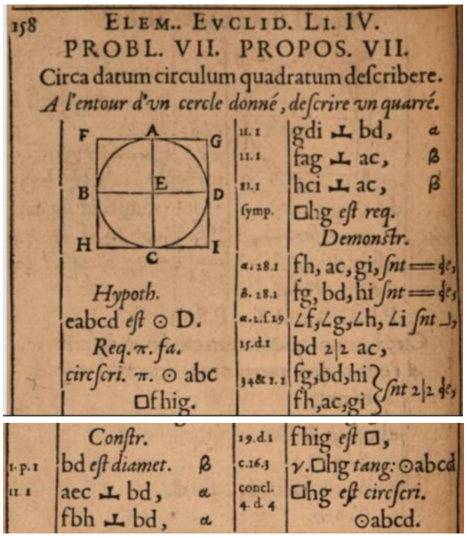
PROBL. 7. PROPOS. 7. 7.

CIRCA datum circulum quadratum describere.

SIT circa datum circulum ABCD, cuius centrū E, describendum quadratum. Ducantur duæ diametri AC, BD, secantes se in E, centro, ad angulos rectos; & per A, B, C, & D, educantur ad diametros lineæ perpendiculares FG, FH, HI, IG, coeuntes in punctis F, H, I, G. Quòd enim coeant AF, BF, patet ex eo, quòd ducta recta AB, faciat cum AF, BF, duos angulos duobus rectis minores: atque ita de reliquis. Dico FHIG, esse quadratum circa circulum datum descriptum. Cùm enim anguli AEB, FBE, sint recti, ᵉ erūt FH, AC, parallelæ; similiterque erunt GI, AC, parallelæ. ᶠ Quare & FH, GI, parallelæ erunt. Eodem modo parallelæ erunt FG, HI. Quoniam igitur parallelogrammum est ACHF, ᵍ erunt latera opposita AC, FH, æqualia, & anguli oppositi ACH, AFH, æquales: Sed ACH, est rectus. Igitur & AFH, rectus erit. Eadem ratione ostendemus angulos H, I, G, rectos esse, & latera HI, IG, GF, æqualia esse diametris BD, AC. Quare cùm diametri sint æquales, erunt & quatuor latera FG, FH, HI, IG, æqualia, ideoque FGIH, quadratum erit; cuius quidem latera circulum tangunt, per corollarium propos. 16. lib. 3. Circa datum igitur circulum quadratum descripsimus. Quod erat efficiendum.

e 28. primi.
f 30. primi.
g 34. primi.

Hérigone (1634e: 158)



158 ELEM.. EVCLID. LI. IV.

PROBL. VII. PROPOS. VII.

Circa datum circulum quadratum describere.

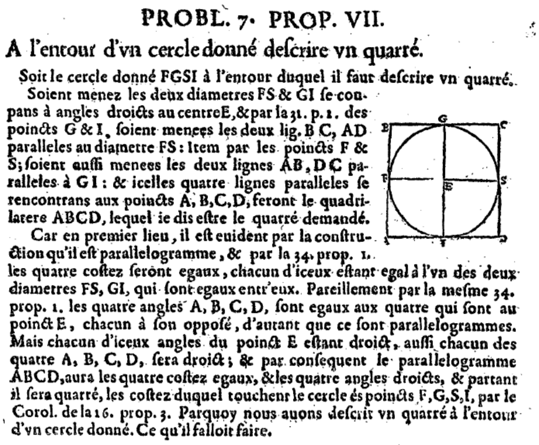
A l'entour d'vn cercle donné, descrire vn quarré.

Hypoth.
eabcd *est* ⊙ D.

Req. π. *fa.*
circscri. π. ⊙ abc
□fhig.

		11.1	gdi ⊥ bd, α
		11.1	fag ⊥ ac, β
		11.1	hci ⊥ ac, β
		symp.	□hg *est req.*
			Demonstr.
		α. 28.1	fh, ac, gi, *snt* = ⫲,
		β. 28.1	fg, bd, hi *snt* = ⫲,
		α. 1. f. 29	∠f, ∠g, ∠h, ∠i *snt* ⊥,
		15.d.1	bd 2|2 ac,
		34 & 1.1	fg, bd, hi } fh, ac, gi } *snt* 2|2 ⫲,
	Constr.	19.d.1	fhig *est* □,
1.p.1	bd *est diamet.* β	c.16.3	γ.□hg *tang:* ⊙abcd
11.1	aec ⊥ bd, α	concl. 4.d.4	□hg *est circscri.*
	fbh ⊥ bd, α		⊙abcd.

Henrion (Euclid 1632: 158)



PROBL. 7. PROP. VII.

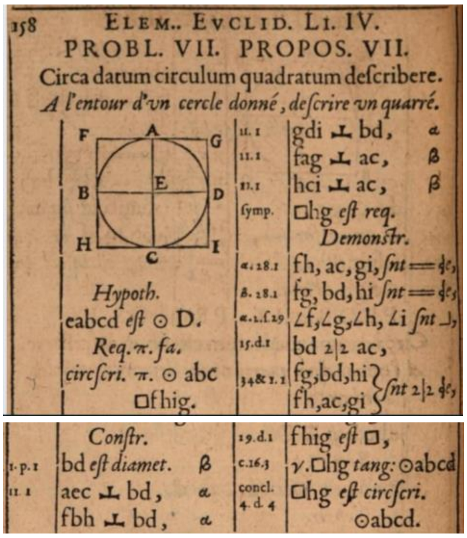
A l'entour d'vn cercle donné descrire vn quarré.

Soit le cercle donné FGSI à l'entour duquel il faut descrire vn quarré.

Soient menez les deux diametres FS & GI se coupans à angles droicts au centre E, & par la 31. p. 1. des poincts G & I, soient menees les deux lig. BC, AD paralleles au diametre FS: Item par les poincts F & S; soient aussi menees les deux lignes AB, DC paralleles à GI: & icelles quatre lignes paralleles se rencontrans aux poincts A, B, C, D, feront le quadrilatere ABCD, lequel ie dis estre le quarré demandé.

Car en premier lieu, il est euident par la construction qu'il est parallelogramme, & par la 34. prop. 1. les quatre costez seront egaux, chacun d'iceux estant egal à l'vn des deux diametres FS, GI, qui sont egaux entr'eux. Pareillement par la mesme 34. prop. 1. les quatre angles A, B, C, D, sont egaux aux quatre qui sont au poinct E, chacun à son opposé, d'autant que ce sont parallelogrammes. Mais chacun d'iceux angles du poinct E estant droict, aussi chacun des quatre A, B, C, D, sera droict; & par consequent le parallelogramme ABCD, aura les quatre costez egaux, & les quatre angles droicts, & partant il sera quarré, les costez duquel touchent le cercle és poincts F, G, S, I, par le Corol. de la 16. prop. 3. Parquoy nous auons descrit vn quarré à l'entour d'vn cercle donné. Ce qu'il falloit faire.

Hérigone (1634e: 158)



158 ELEM.. EVCLID. LI. IV.

PROBL. VII. PROPOS. VII.

Circa datum circulum quadratum describere.

A l'entour d'vn cercle donné, descrire vn quarré.

Figure 6: Euclid's Elements*, book 4, proposition 7*

The text of the Latin statement of the proposition is identical in both versions of the *Cursus*, while the only difference between the French statements is a single comma. In the rest of the proposition, however, Clavius and Henrion provide traditional verbal explanations while Hérigone uses only his abbreviations, symbols, and references to previously established results, as part of his new method. In addition, Hérigone divides his demonstrations into the separate sections promised in the address to the reader in volume one, making them more accessible to his inexpert audience: the hypothesis (*Hypoth.*), what is being sought (*Req.*), the construction (*Constr.*), and the demonstration (*Demonstr.*). None of these are present in either Clavius's text or Henrion's translation of it.

This brief comparison of Hérigone's version of Euclid's *Elements* in relation to Clavius's text, which he acknowledges using, and Henrion's French translation of Clavius's text, which he does not mention, demonstrates that it is not accurate simply to state that Hérigone copied both texts. Hérigone's approach to Clavius's Latin text is multi-faceted: he states in the prolegomena that he has followed the order for the *Elements* established by Clavius. He omits some of the text of Clavius's *Elements*: while he uses some of Clavius's text for the prolegomena, definitions and propositions in his own text, he edits the prolegomena and the text of the definitions, selecting only a few phrases for his own use, and replaces the text in the demonstrations of the propositions with his own symbolic system.[69] Hérigone also edits Henrion's text, but often to a greater extent than Clavius's, and similarly replaces the mathematical demonstrations entirely. In both cases, Hérigone can be said to have rewritten the texts of the *Elements* to suit his own purposes of communicating more directly and simply with the non-specialist segment of his audience. As a rewritten version of Clavius's and Henrion's texts, Hérigone's texts of the *Elements* can therefore be characterised as one of the two types of retranslation identified by Isabelle Vanderschelden: revision of earlier translations (2000: 1154). In this respect, Hérigone's approach is similar to that of some of the sixteenth-century translators of recovered ancient texts mentioned in section 2.2.1 above, as they also used previous translations as starting points to revise and update the texts.[70]

There is strong evidence for describing Hérigone's use of Stevin's work on statics as selective rewriting rather than retranslation of the entire work. René Dugas suggests that the mechanics chapter in volume three of the

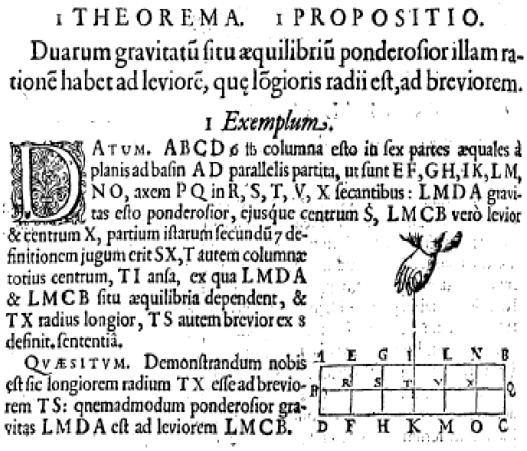
[69] Massa Esteve reaches the same conclusion in her research, stating that Hérigone uses the statements of definitions and propositions in Clavius's translation of the *Elements*, but reformulates Clavius's explanations and demonstrations symbolically and, unlike Clavius, divides the demonstrations into separate sections (2010: 175–76). She reaches a similar conclusion in her research on Viète: 'although Hérigone generally used Viète's statements, his notation, presentation style, and procedures in his algebraic proofs were quite different from Viète's' (2008: 285).
[70] Other sixteenth-century retranslations were based on the original texts, creating entirely new translations, which is the other form of retranslation identified by Vanderschelden (2000: 1154–55).

Cursus was ‘inspired’ by Stevin (1988: 149), implying that Hérigone took what he needed from Stevin rather than using it as a basis for his own translation. As with the *Elements*, Hérigone’s chapter is structured in a similar way to its source: a series of definitions and postulates (or axioms) precedes a series of propositions on various aspects of mechanics. For the most part, however, Hérigone uses only small parts of Snel’s and Girard’s Latin and French versions of Stevin’s work, preferring to select only those segments that are useful to him. The difference between the works can be seen in the names of the texts and the definitions with which the authors begin their texts. Stevin’s work is about ‘statics’, the part of mechanics that is devoted to bodies at rest and forces at equilibrium. He defines the subject matter in his first definition as the science of ratios, proportions, and properties of the weights or gravity of bodies (1605: 5; 1634b: 434). Hérigone’s subject matter, on the other hand, is mechanics itself, which, in his first definition, he characterises as the science of moving forces (1634h: 283). In addition, within the definitions section as a whole, only four of Hérigone’s eleven definitions correspond to Stevin’s fourteen.

When he does use Stevin’s definitions as his direct inspiration, in the translations provided by Snel and Girard, Hérigone edits the text and ensures it is equivalent in both versions of the *Cursus*. In his second definition, for example, Hérigone uses similar wording to that used in both the Latin and French translations of Stevin’s second definition, but shortens it: Snel’s ‘Gravitas corporis est potentia descensu in dato loco’ [The gravity of a body is the power of its descent in a given location] (Stevin 1605: 5) is rendered as ‘Gravitas corporis est eius potentia descensus’ (Hérigone1634h: 283), while Girard’s French translation, ‘La pesanteur d’un corps, c’est la puissance qu’il a de descendre, au lieu proposé’ (Stevin 1634b: 434) becomes ‘La pesanteur d’un corps est la force qu’il a de descendre’ (1634h: 283). In both cases, Hérigone omits the need in statics for a ‘given location’ but retains the primary idea of gravity as a descending ‘force’, which fits well with the notion of mechanics as the science of movement.

There is very little commonality between the propositions that make up most of Hérigone’s chapter and Snel’s and Girard’s translations of Stevin’s work: even more than with the definitions, Hérigone’s chapter makes little use of Stevin’s work. As can be seen in figure 7 below, even on the rare occasions where Hérigone does use Stevin's propositions, he edits them, ensuring they are equivalent in the two versions in the *Cursus*. The first proposition in both Stevin's work and Hérigone's chapter covers similar ground, dealing with the ratio of distances in weights in balance, but Hérigone rewrites Stevin's proposition in both languages.

Snel (Stevin 1605: 12)



1 THEOREMA. 1 PROPOSITIO.

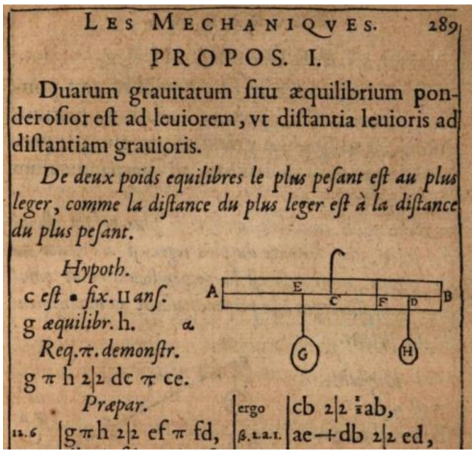
Duarum gravitatũ ſitu æquilibriũ ponderoſior illam rationẽ habet ad leviorẽ, quę lõgioris radii eſt, ad breviorem.

1 *Exemplum.*

DATUM. ABCD 6 ℔ columna eſto in ſex partes æquales à planis ad baſin AD parallelis partita, ut ſunt EF, GH, IK, LM, NO, axem PQ in R, S, T, V, X ſecantibus: LMDA gravitas eſto ponderoſior, ejuſque centrum S, LMCB verò levior & centrum X, partium iſtarum ſecundũ 7 definitionem jugum erit SX, T autem columnæ totius centrum, TI anſa, ex qua LMDA & LMCB ſitu æquilibria dependent, & TX radius longior, TS autem brevior ex 8 definit. ſententiâ.

QVÆSITVM. Demonſtrandum nobis eſt ſic longiorem radium TX eſſe ad breviorem TS: quemadmodum ponderoſior gravitas LMDA eſt ad leviorem LMCB.

Hérigone (1634h: 289)



LES MECHANIQVES. 289

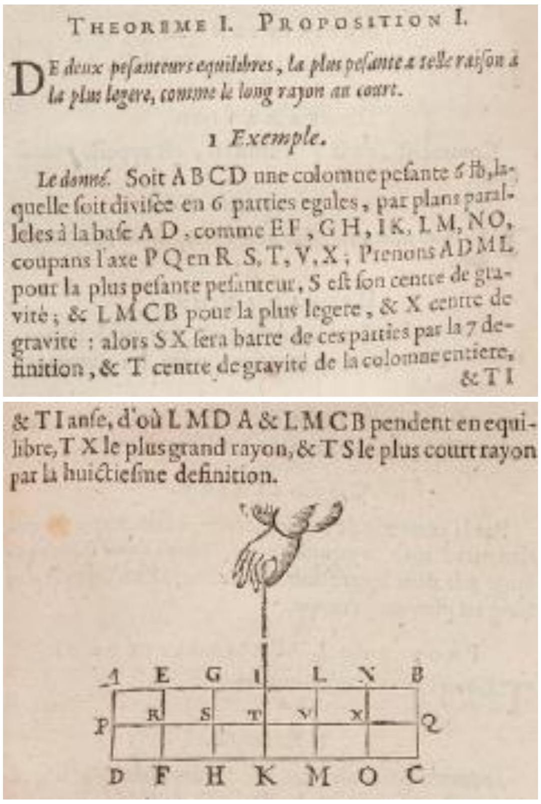
PROPOS. I.

Duarum grauitatum ſitu æquilibrium ponderoſior eſt ad leuiorem, vt diſtantia leuioris ad diſtantiam grauioris.

De deux poids equilibres le plus peſant eſt au plus leger, comme la diſtance du plus leger eſt à la diſtance du plus peſant.

Hypoth.
c *eſt* • *fix.* ⊔ *anſ.*
g *æquilibr.* h.
Req. π. *demonſtr.*
g π h 2|2 dc π ce.
Præpar.
11.6 |g π h 2|2 ef π fd, | ergo β.1.2.1. | cb 2|2 ⁝ab, ae ⫠ db 2|2 ed,

Girard (Stevin 1634b: 436–37)



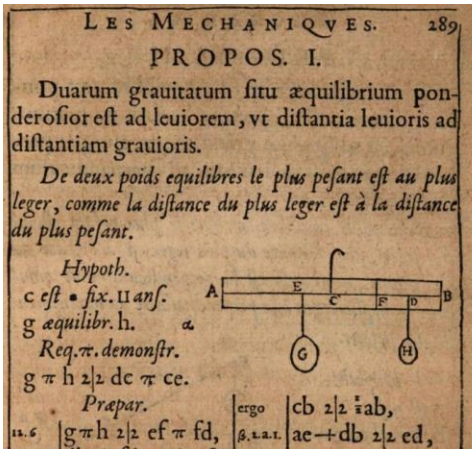
THEOREME I. PROPOSITION I.

DE deux peſanteurs equilibres, la plus peſante a telle raiſon à la plus legere, comme le long rayon au court.

1 *Exemple.*

Le donné. Soit ABCD une colomne peſante 6 ℔, laquelle ſoit diviſée en 6 parties egales, par plans paralleles à la baſe AD, comme EF, GH, IK, LM, NO, coupans l'axe PQ en R, S, T, V, X; Prenons ADML pour la plus peſante peſanteur, S eſt ſon centre de gravité; & LMCB pour la plus legere, & X centre de gravite: alors SX ſera barre de ces parties par la 7 definition, & T centre de gravité de la colomne entiere, & TI anſe, d'où LMDA & LMCB pendent en equilibre, TX le plus grand rayon, & TS le plus court rayon par la huictieſme definition.

Hérigone (1634h: 289)



LES MECHANIQVES. 289

PROPOS. I.

Duarum grauitatum ſitu æquilibrium ponderoſior eſt ad leuiorem, vt diſtantia leuioris ad diſtantiam grauioris.

De deux poids equilibres le plus peſant eſt au plus leger, comme la diſtance du plus leger eſt à la diſtance du plus peſant.

Hypoth.
c *eſt* • *fix.* ⊔ *anſ.*
g *æquilibr.* h.
Req. π. *demonſtr.*
g π h 2|2 dc π ce.
Præpar.
11.6 |g π h 2|2 ef π fd, | ergo β.1.2.1. | cb 2|2 ⁝ab, ae ⫠ db 2|2 ed,

Figure 7: Stevin's and Hérigone's first propositions

Hérigone clearly uses Snel's and, to a lesser extent, Girard's versions of the text at the beginning of the proposition, but rewrites the rest of the proposition for his own purposes, making it more detailed in the process. He also replaces Girard's 'pesanteur' with 'poids' (both mean 'weight' and imply gravitational force). He uses a different diagram to Snel and Girard (and, by extension, Stevin, whose diagram Snel and Girard either copied exactly or for which they succeeded in finding the plates). Figure 7 also shows again, as with Euclid's *Elements*, how Hérigone's demonstrations differ from those of other mathematicians: while Stevin's demonstrations in both Latin and French are entirely verbal, Hérigone's use only symbols and abbreviations. Stevin's demonstrations are, however, divided into sections labelled 'Datum', or 'Le donné', and 'Quæsitum' (for information given and required) to make the stages of the proposition clearer for his audience, in a similar manner to Hérigone. It should be clear from this snapshot of Hérigone's work in the 'Mechanics' chapter in the third volume of the *Cursus* that he may have been influenced by a variety of earlier sources, and, in Stevin's case, may have used small amounts of the text of the Latin and French translations but, even on the few occasions when he did so, he generally rewrote the text for his own purposes, ensuring that the two versions of his own text corresponded as closely as possible.

What are the implications of Hérigone's methods for compiling the *Cursus* for its status as a self-translation? When he created the *Cursus* as a compilation of mathematical knowledge, Hérigone was following in a number of established traditions. For example, summaries of knowledge that could be accessed by a literate lay population were produced in ancient Greece; in fact, the practice was so common that texts were copied and recompiled several times, with no concerns about plagiarism (Montgomery 2000: 25). Before the advent of printing, mediaeval encyclopaedic compilations, which provided access to original authoritativative sources, were used for teaching purposes in the monasteries, schools and universities (Keen 2013: 278–79). Following the invention of the printing press in the Renaissance, an increased range of topics was compiled (Blair 2013: 380). Blair sees this increase in compilation as 'a cultural impulse that sought to gather and manage as much information as possible' for the public good (2013: 382). During this period, a new tradition of comprehensive printed summaries of mathematical knowledge began with publication of Pacioli's *Summa* (Katz 2014: 391). And, by the Early Modern period, it was not unusual for textbooks to be compilations (Grafton 2008: 25). Typical of the comprehensive compilations of knowledge was the four-volume *Encyclopædia* (1630) of Johann Heinrich Alsted (1588–1638) that subdivided mathematics into the traditional quadrivium and the newer mixed mathematical topics in a similar way to Hérigone (Blair 2013: 392). Later seventeenth-century mathematics textbook compilers, such as Gaspar Schott (1608–1666), considered Alsted and Hérigone to be their direct predecessors (Knobloch 2011: 232).

As Blair notes, '[e]arly modern compiling was [...] deeply indebted to a long medieval tradition' (2010: 175). In the Middle Ages, one view of the compiler was as a writer who 'scribit aliena, addendo, sed non de suo' [writes the work of others with additions which are not his own] (Bonaventure 1882b: 14).[71] Compilers reported the words of authors; they offered no authority of their own, but received it from the compiled material (Bolduc 2006: 32; Blair 2010: 175). Authors (*auctores*, or 'augmenters'), on the other hand, produced mostly their own words, with additions from others for the purposes of confirmation (Bonaventure 1882b: 14). They were perceived as 'individuals who *reshaped* material for their purpose', not authors in the modern sense of the word (Finkelstein and McCleery 2005: 69). As writing became a more individualised activity in the Renaissance, following the invention of the printing press, so the role of the author began to change (Finkelstein and McCleery 2005: 69–70). Even then, some of the greatest writers of the Renaissance and Early Modern period, including John Milton (1608–1674) and William Shakespeare (1564–1616), used translations, paraphrases and direct copying of other writers' work in their own (Rose 1993: 2). Ideas of authorial production and ownership of original material took a long time to emerge after the advent of printing (Hesse 2002: 28–29).

As in the Middle Ages and the Renaissance, 'it was not uncommon in early modern scholarship to borrow words and ideas and not credit sources' (Saiber 2017: 65). Many notable mathematicans who preceded Hérigone, including some whose work he used in the *Cursus*, also used prior work as a

[71] The translation is due to Eisenstein (1979: I, 121).

source of the results they presented. Victor Katz states that Pacioli used the works of Fibonacci and others in the *Summa* (2014: 391), while Merzbach and Boyer assert that, in creating the *Elements*, 'Euclid himself made no claim to originality, and it is clear that he drew heavily from the works of his predecessors. It is believed that the arrangement is his own' (2010: 94). Furthermore, as Bartel van der Waerden notes, some of the problems in Viète's *Zeteticorum libri quinque* [Five Books on Zetetics] (1593) were taken from Diophantus's *Arithmetica* and Stevin's 'highly original books on mechanics were inspired by Archimedes' (1985: 64, 68).

Alsted's behaviour in compiling his *Encyclopædia* only four years before the first four volumes of the *Cursus* were published is closest to Hérigone's *modus operandi* in the *Cursus*: according to Blair, expert analysis has shown that Alsted used work from nearly eighty sources, but rarely credited them (2013: 393). He did, however, place himself in a long scholarly tradition by naming eighteen of his predecessors (Blair 2013: 393). In a similar vein, while neglecting to mention a number of his sources, Hérigone devoted a part of the sixth volume of the *Cursus* to listing the 'principaux Autheurs qui ont inventé ou escrit quelque chose des Mathematiques' [principal Authors who invented or wrote on Mathematics] from Ancient Greece to Descartes (1642b: 200–62). This is an exercise in scholarly rhetoric where Hérigone is signalling his belief that he belonged in the company of such mathematical authorities, in a similar fashion to the mediaeval compilers, and in a similar way to contemporaries such as Mersenne, as will be seen in chapter 4. As with Alsted, Hérigone drew heavily on the work of some of his predecessors, crediting many but not all of them, adapted their findings for his own use; he then demonstrated their work using his own unique symbolic methodology. The process he used is accurately characterised by Descotes as 'des adaptations d'auteurs classiques' [adaptations of classical authors] (2006: 240). In addition to the recognisable and acknowledged sources, the *Cursus* is also composed of adaptations — translations, rewrites and symbolisation — of mathematics that had been passed down through several generations of mathematicians and adapted and rewritten in turn by a range of other mathematicians. It can therefore be concluded that, as Hérigone, like Alsted, compiled the *Cursus* for his own educational purposes, reflecting on the text in both languages as he reconfigured it, in an era when the concept of intellectual ownership was more fluid than it is now, he can clearly be considered as the bilingual author of the *Cursus*.

3.4 Similarities and differences between the *Cursus* and the *Cours*

3.4.1 The paratext

In this section, I will focus on paratext that 'conveys comment on the text, or presents the text to readers, or influences how the text is received' (Batchelor 2018: 12). In the *Cursus*, this means the address to the reader and the prolegomena in volume one and the prefaces in volumes two to five. The address to the reader in volume one, which introduces Hérigone's new method and so acts as a preface to the entire *Cursus*, is particularly interesting as the location of small but significant differences between the Latin and French texts, though it is not the only such place. Kevin Dunn has found that the writer's presence in Early Modern prefaces is 'always a rhetorical figure, [...] an attempt at self-authorization' (1994: 11). This is true of the address to the reader and the prolegomena, where Hérigone sets out to persuade the reader of the value and importance of his new approach, using references to classical authorities and a range of rhetorical techniques.

The authorities Hérigone invokes in the address to the reader include the Greek poet, critic and scholar, Callimachus (*c*. 305–*c*. 240 BCE), the Greek philosopher, Heraclitus (*c*. 540– *c*. 480 BCE), as well as Cicero (1634b: ix–x). Callimachus's epigram about the evils of over-long books is used to justify the concise nature of Hérigone's method, while the other two authorities serve to justify the need for clarity and intelligibility in the method. It is interesting to note from a self-translation perspective that there are differences in the way these authorities are introduced to the text that suggest that Hérigone had slightly different views of the capabilities of his different audiences. The majority of the text is similar in both languages, but Callimachus's epigram about long books being evil is quoted in Greek in the Latin text (as 'μέγα βιβλίον μέγα κακόν' [a big book is a big evil]), but is translated into French in the French text (as 'un grand Livre est un grand mal').[72] Furthermore, Heraclitus's Greek nickname of

[72] I am indebted to Alison Sharrock and Rhiannon Ashley for their English translation of Callimachus's Greek epigram (2002: 145).

‘σκοτινον’ [the Obscure] is translated into French as ‘le Tenebreux’ (1634b: x). Hérigone presumably translates the Greek text because he believes that readers whose Latin is not strong enough for them to read the Latin version of the paratext will be put off by an epigram and a nickname quoted in another classical language. Certainly, Greek was considered the less important of the classical languages in the colleges at this time and was therefore known to fewer people (Viguerie 1978: 163). It is likely that Hérigone altered these small sections of the paratext in order to keep to his stated aim of not including anything that would be difficult or obscure that would dishearten the inexpert reader.

Hérigone uses the rhetorical technique of *synonomia* to add explanatory synonyms for mathematical terms in the French paratext, again probably from a desire to ensure that the French-only readers of the texts would not be at a disadvantage.[73] This can be seen on two occasions in the prolegomena. In the second prolegomenon, the ‘Divisio Elementorum Euclidis’, or ‘Division des Elements d’Euclide’ [Division of Euclid’s *Elements*], Hérigone explains how he has divided Euclid’s works into four sections. He adds an explanation to his description of the second of the sections: in Latin he states that ‘Secunda [...] passiones numerorum perscrutatur’ [In the second (section) (...) the properties of numbers are investigated] (1634c: xvi). The expression ‘passiones numerorum’ was commonly used in mediaeval mathematics and philosophy to refer to the properties of numbers by, amongst others, Thomas Aquinas in his fifth book of commentary on Aristotle’s *Metaphysics* (1270–72) (1995: 362).[74] In French this is rendered as ‘La seconde [...] recherche les passions et proprietez des nombres’ [The second (...) investigates the ‘passions’ and properties of numbers] (1634c: xvi). The French-reading audience is not expected to understand the meaning of ‘passiones numerorum’, so the meaning is explained to them using a combination of the abstract French equivalent ‘passions des nombres’ and the more general ‘proprietez’. Similarly, in the third prolegomenon, the ‘De principiis Mathematicis’, or ‘Des principes des Mathematiques’ [On the Principles of Mathematics], Hérigone outlines what he considers to be the third main mathematical principle — ‘axiomata’, or ‘axiomes

[73] *Synonomia* is defined in general as ‘the use of several synonyms together to amplify or explain a given subject or term. A kind of repetition that adds emotional force or intellectual clarity’ (Burton 2016).
[74] Aquinas refers to ‘passiones numerorum, quæ sunt commensuratio, proportio, et huiusmodi’ [the properties of numbers, which are commensuration, ratio and the like] (1995: 362).

ou maximes' [axioms or principles] — choosing to accompany the technical mathematical term 'axiome' with the more general philosophical term 'maxime' (1634c: xviii). In both cases, Hérigone's choices suggest that he was not confident that his French readership would understand the technical terms without the more general synonym.

Hérigone also uses repetition, by means of the rhetorical technique of *conduplicatio*, and contrast, by means of *antithesis*, on this occasion to emphasise his goal of clarity and concision over obscurity and redundancy. The main themes are initially underlined by repetition of nouns and adjectives related to brevity and ease of use and understanding: 'intelligible' (four times), 'intelligence' (three times), 'briefve' (twice), and 'briefveté' [comprehensible, comprehension, brief, and brevity] in French, and their Latin equivalents: 'perspicuum' and 'intellectus' (three times), 'perspicuitas' and 'intelligentia', and 'brevis' (twice) and 'brevitas' (1634b: ix–xii). The themes are then further highlighted by contrast in the French text with 'obscur' (four times), 'difficile', 'difficulté' and 'superflu' [opaque, difficult, difficulty, and superfluous], and by 'obscuro' (three times), 'difficilis', 'difficultas' (twice) and 'superfluus' in the Latin text (1634b: ix–xii). In both the Latin and French texts, Hérigone is keen to justify and communicate his mission to make his text concise, intelligible and easy to use for all readers, irrespective of linguistic or mathematical background.

The final notable difference between the paratexts in the two versions of the text involves a change to a message in the text to support the potentially less confident readers of the French text: in the preface to volume five, Hérigone adopts different attitudes to his work for his different audiences. In both versions, Hérigone explains that he has left its subject matter, astronomy, to the end of the original five-volume *Cursus*. In the Latin version of the text, this is presented simply as a positive decision: 'cuius tractatio in extremum operis reposita est, ut pulcherrimo fine concluderetur' [the treatment of which is put back to the end of the work, so that it should have a most beautiful end] (1637a: iv). By contrast, Hérigone feels the need to empathise with his less mathematically advanced French audience, telling them that astronomy 'a esté reservée au dernier lieu, afin que ce long et ennuyeux travail finit agreablement' [has been kept until last so that this long and tiresome work should finish pleasantly] (1637a: iv). Only the French-only readership, with a presumed inferior understanding of mathematics, is thought to need convincing and reassuring that the ‘long and tiresome’ work will soon be over.

The evidence presented in this subsection clearly shows that, in order to fulfil his dual mission to be clear and concise, Hérigone altered the text between the two versions of his paratext in small but significant ways. The majority of the rhetorical techniques and text are the same in both languages, but it is the differences that shed light on Hérigone’s perception of his two principal audiences: he clearly appears to have worried on occasion that including in the French text exactly the same material as in the Latin text would lead to a loss of clarity, potentially discouraging his French audience. Consequently, he employed a number of strategies to support and convince them, translating Greek into French, adding synonyms as explanatory text with some mathematical terminology, and giving them reassuring and persuasive messages.

3.4.2 The Practical Arithmetic

Hérigone deals with combinatorics and the Arithmetic Triangle in the two books in the second volume of the *Cursus*: he includes a diagram for generating binomial coefficients that resembles Pascal’s Arithmetic Triangle as part of his sections on the four rules for combining algebraic terms in chapter III of the book on algebra (1634g: 17), and discusses combinations in chapter XV of the book on practical arithmetic (1634f: 119–24). Both books include a combination of text and demonstrations that are typical of the *Cursus* as a whole but I have chosen to examine the Practical Arithmetic as it contains more text on the subject of combinatorics and a wider range of topics, and is therefore more likely to provide greater insight into how Hérigone translates his own work. The analysis of the Practical Arithmetic will cover three main topics. First, I will briefly examine the content and structure of the book and its mathematical features in order to provide background information for the rest of the subsection. This will be followed by a comparative study of the similarities and differences between the two versions of the book, first in Hérigone’s use of mathematical terminology, rhetoric and symbols and then in relation to other aspects of the texts.

The title given to the Practical Arithmetic in the text is 'ARITHMET. PRACT.': the abbreviated nature of the title means that it applies in both languages, another indication of Hérigone's merging of the two languages, discussed in section 3.3.1.[75] The book collects together a range of information from a number of sources and presents it in eighteen chapters. A number of the chapters include what Hérigone refers to as 'logistic' as it relates to whole numbers, fractions and decimals.[76] Other topics covered in the book include weights and measures, ratio and proportion, the mixing of quantities, the finding of roots, combinatorics, memorisation methods, the church calendar and conversions between roman and arabic numerals.[77]

The majority of the chapters — fourteen in total — consist of a series of propositions that contain a number of examples and demonstrations involving calculations. These chapters also include other features of mathematical texts, including scholia, one summarising the four rules of number (1634f: 27) and another explaining the rule of false position (1634f: 111), a corollary to the definition of decimals (1634f: 32), and a lemma to the second proposition on the arithmetic of fractions showing how to find the highest common factor of the numerator and denominator (1634f: 58). These chapters are a mix of text presented in bilingual columns and demonstrations covering the entire page and containing a minimum of text in either language. The other four chapters (the first two and final two) deal mainly with information and so consist principally of bilingual text and few mathematical features or demonstrations. The content and mathematical features are common to both versions of Hérigone's text.

The mixed composition of chapters in the Practical Arithmetic highlights a conflict between two contrasting aims in the *Cursus*: on the one hand, Hérigone is seeking to create a textbook containing the sum of mathematical knowledge while on the other he is attempting to present this knowledge not in the format of a textbook, but in the manner favoured by authorities, both ancient and

[75] 'Arithmetica practica' and 'Arithmetique pratique'.
[76] 'Logistic' was a term used by Diophantus in his *Arithmetica* to mean 'the computational arithmetic used in the solution of practical problems' (Vogel 1981: 111). The subject derived from the Ancient Greek desire to distinguish 'between mere calculation, on the one hand, and what today is known as the theory of numbers, on the other' (Merzbach and Boyer 2010: 56). In his etymological dictionary of mathematical terms, Hérigone states simply that 'Logistique' derives from the Greek for the verb 'to calculate' (1637c: 458). The logistics sections of the *Cursus* summarise computation methods involving the arabic numerals.
[77] Arabic numerals, which made calculations easier (Van der Waerden 1985: 33), only finally replaced the less flexible roman numerals around the end of the fifteenth century (Bellos 2020: 126).

modern, as required in mathematical treatises.[78] In the Practical Arithmetic, this conflict can be seen most clearly in the contrast between the text of the propositions and accompanying examples on the one hand and the demonstrations and references to Euclid on the other.

Very few of the propositions in the Practical Arithmetic conform to traditional expectations, as they are not statements that may or may not be true followed by demonstrations using the elements highlighted by Proclus.[79] In general, the propositions are either definitions followed by explanations and demonstrations, or simply explanations and demonstrations. Examples of both types can be found at the beginning of chapter VI on arithmetic with fractions. The first proposition begins by defining a fraction and its constituent parts before going on to describe how to write a fraction and to explain the concept of equivalent fractions (1634f: 53–55). The second proposition is simply a sequence of examples showing, for example, how to change improper fractions into proper fractions and decimals (1634f: 55–60). This reliance on explanations and demonstrations is characteristic of textbooks. The same is true of the subject matter of the examples in the Practical Arithmetic: topics covered include the cost of bread (1634f: 82) and of borrowing money (1634f: 83); the logistics of feeding a town under siege (1634f: 83); mixing medicines in an apothecary (1634f: 99–100); and the profit to be made from selling grain (1634f: 89), from pooling money for shared profits (1634f: 90–92), or from lending money (1634f: 97–99). It is not clear whether Hérigone invented the examples himself or selected them from prior works, but the examples are clearly relevant to the audiences for both versions of the *Cursus*.

The content of the propositions and examples contrasts very strongly with the demonstrations and references to the *Elements* that feature in a number of the chapters in both languages, both of which use the language of mathematical treatises, albeit in abbreviated form. In the demonstrations, the working is laid out using the headings in Hérigone's concise new method, though not all are used in every demonstration. The most common sequences

[78] Grafton notes that, when Early Modern authors recommended books to those who wanted to learn a new discipline, rather than recommend textbooks, they tended to suggest works by ancient or contemporary authorities, whether these works were originally intended to serve as the basis of instruction or not (2008: 13–16). The *Cursus* is a product of the conflict between two contrasting desires: to create a textbook, which is not the preferred choice, but to include authoritative works, which is.

[79] The mathematical definition of a proposition is a statement that is 'put forward' and which may be true or false (Schwartzman 1994: 175).

are the bilingual abbreviations ‘Exempl.’, ‘Hypoth.’, ‘Operat.’, ‘Req. est’ (1634f: 47, 48, 50, for example) and ‘Hypoth.’, ‘Operat.’, ‘Req. est’ (1634f: 29, 41, 47, 89, for example). They correspond to the sequences (‘exemplum’ or ‘exemple’), ‘hypothesis’ or ‘hypothese’, ‘operatio’ or ‘operation’, ‘requisitum est’ ‘le requis est’ [example, hypothesis, operation, solution required]. Other sequences are variations on this ordering that miss out one or two of the elements or, in one or two rare cases, change the order. In a small number of cases, the demonstration is completed by an examination, or proof (‘examen’ in both languages) (1634f: 28–30, 86). The references Hérigone makes in both Latin and French in the text to Euclid’s propositions from volume one are also characteristic of mathematical treatises rather than a textbook. For example, Hérigone invokes ‘7 axioma septimi’ or ‘le 7 axiome du 7’ [the 7th axiom in the seventh book] in his proof for multiplication of whole numbers (1634f: 20), and ‘9 axioma septimi’ and ‘le 9 axiome du 7’ [the 9th axiom in the seventh book] in his proof for division of whole numbers (1634f: 26).

The most striking aspect of the mathematical features of the text discussed above — the subject matter, format, layout, and structuring of the demonstrations — is the similarity of the two versions. In addition, the varying degree of mathematical complexity of the examples, demonstration and references to Euclid is the same for both versions of the *Cursus*. From a self-translation perspective, however, the most important consideration is the degree of similarity or difference between the texts of the two versions, both the variations between the Latin and French versions of Hérigone’s text and what Hokenson and Munson described as ‘the textual intersections and overlaps of versions’ (2007: 4). Consequently, the rest of this subsection will compare the two versions, beginning with the mathematical language contained in them: first mathematical terms, before moving on to mathematical rhetoric and finishing with a brief analysis of the use of arithmetic signs.

Mathematical terminology abounds in both texts, as would be expected in a mathematical textbook. Most of the terms that Hérigone uses had been established in both Latin and French (from mediaeval Latin) for centuries.[80]

[80] As can be seen in appendix 3, the majority of the terms were established in both French and mediaeval Latin before the mid-seventeenth century: ‘arithmétique’, ‘addition’, ‘soustraction’, ‘multiplication’ and ‘division’ and the verbs that accompany them (from the Latin terms ‘additio’, ‘subtractio’, ‘multiplicatio’ and ‘divisio’), weights and measures such as ‘aulne’, ‘once’, ‘livre’ and ‘pinte’ (from the Latin ‘ulnis’, ‘uncia’,

‘Zero’ is the only one of these terms to cause Hérigone any uncertainty regarding his audience’s understanding, in both languages. When introducing it, he states that ‘Decima autem figura et ultima o, nihil per se significant, diciturque cifra, vel zero’ and ‘Mais la dixiesme et derniere figure o, ne signifie rien de soy, et s’appelle chifre, ou zero’ [But the tenth and final number 0 has no meaning on its own, and is called ‘cypher’, or zero] (1634f: 2). It is referred to by the single terms ‘cifra’ in Latin and ‘zero’ in French throughout the rest of the text (1634f: 19 and 25, for example).[81] Some of the more recent terminology came from the bilingual works of sixteenth-century mathematicians such as Peletier: he introduced terms such as ‘exposant’ and ‘produit’ from the equivalent Latin terms ‘exponens’ and ‘productum’ [exponent and product] that were in common usage in the early seventeenth century (CNRTL 2012). Hérigone uses the old French term for ‘tithes’ or ‘tenths’ in ‘nombres de la dixme’ as the equivalent of ‘numerus decimarum’ for decimal numbers, probably copying the use of the term (as ‘disme’) in Girard’s 1634 translation of Stevin’s *De thiende* [Tenths].[82]

Just as with the discussion above reflecting on the differences in usage of well-established mathematical terms, Hérigone’s use of terminology for permutations and combinations is interesting in a number of ways, mainly because of a probable misunderstanding of his source. In chapter XV of the Practical Arithmetic, he uses the cognate pairs ‘conjunctio’ and ‘conjonction’ for ‘combination’ and ‘transpositio’ and ‘transposition’ for ‘permutations’ (1634f:

‘libra’ and ‘pinta’ respectively), and also for terms such as ‘aire’ (‘area’), ‘decuple’ (‘decuple’), ‘diviseur’ (‘divisor’), ‘égaler’ (‘æquo’), ‘fraction’ (‘fractio’), ‘nombre’ (‘numerus’), ‘progression’ (‘progressio’), ‘quotient’ (‘quotiens’), ‘racine’ (‘radix’), ‘raison’ (‘ratio’), ‘unité’ (‘unitas’), ‘dénominateur’ and ‘numérateur’ (‘denominator’ and ‘numerator’), the cardinal and ordinal numbers, and the approximations ‘dizaine’ and ‘centaine’ (‘denarii’ and ‘centenarii’). Only a few of the older established French terms in the text did not come directly from their Latin equivalents, including ‘côté’ (‘latera’), ‘degré’ (‘gradus’), and ‘zéro’ (‘cifra’), though all three came from Latin vocabulary: ‘côté’ derived from the classical Latin adjective ‘costatus’, while ‘degré’ came from ‘gradus’ with a prefix added. The mediaeval Latin (and Old French) form ‘cifra’ and the modern French ‘chiffre’ (written as ‘chifre’ by Hérigone) were direct borrowings from the Arabic ‘ṣifr’ meaning ‘empty or zero’, while ‘zéro’ is derived from the mediaeval Latin ‘zephirum’, which was itself originally derived from ‘ṣifr’ (CNRTL 2012). According to Alain Rey and Josette Rey-Debove, ‘zero’ replaced the Old French ‘cifra’ from 1485 (1983: 2127). English translations of the terms can be found in appendix 3.

[81] Le Dividich notes that not all mathematical vocabulary was used in a settled, uniform manner in the seventeenth century and she cites ‘chiffre’ as an example: when originally borrowed from the Arabic ‘ṣifr’, it simply meant ‘zero’, but, by the fifteenth century, also meant ‘figure’ or ‘digit’. It was still being used in both senses as late as the 1660s, after publication of the *Cursus* (2000: 344).

[82] ‘In *De thiende*, [...] published in 1585, Stevin introduced decimal fractions for general purposes and showed that operations could be performed as easily with such fractions as with integers. [...] [A]lthough Stevin’s notation was somewhat unwieldy, his argument was convincing, and decimal fractions were soon generally adopted’ (Minnaert 1981: 48). Girard’s translation was published in the same year as the first four volumes of the *Cursus*. In the sixth volume of the *Cursus*, in an introduction to chronology, Hérigone acknowledges Stevin’s role as ‘le premier autheur de la Dixme’ [the first author to write about Decimals] (1642b: 240). ‘Dixme’ was replaced by ‘décimal’ in the late seventeenth century (Hauchecorne 2003: 49).

119–24). As noted in section 3.3.2, Hérigone almost certainly based his knowledge of combinatorics either directly or indirectly on the work of Clavius, who discusses combinatorics in a digression in his *In sphæram Joannis de Sacro Bosco commentarius* [Commentary on Sacrobosco's *De sphæra*] (1570), a work about astronomy and geography: Hérigone's chapter includes an example used by Clavius where the number of possible combinations of the seven known planets is calculated (Clavius 1570: 48; Hérigone 1634f: 122–23).[83] In general in his discussion of combinatorics, Clavius uses the term 'combinatio' for combinations and 'conjunctio' for permutations: he uses 'combinatio' when calculating the number of combinations of Aristotle's four elements and 'conjunctio' to find the six possible arrangements, or permutations, of the letters in the word 'AVE', for instance (1570: 47–48). However, in a section between these two examples, Clavius uses the term 'conjunctio' in a number of examples involving combinations, including the planets example used by Hérigone. Having followed Clavius in the use of 'conjunctio' for combination in this case, Hérigone requires different terms for permutations in the brief example he provides at the end of the chapter and so chooses 'transpositio' and 'transposition' (1634f: 123–24). Although Hérigone does not follow Clavius in his use of 'combinatio', this is the term that is still used in mathematics today, as 'combination' in English and 'combinaison' in French, for example. 'Combinatio' and its earlier French cognate 'combination' are the terms used by Mersenne in the *Liber de cantibus* and *Livre des chants* to describe both combinations and permutations, as will be seen in chapter 4, while Pascal uses the Latin term in the *Combinationes* and the newer French word in the *Usage pour les combinaisons*.

Although he chooses different terminology to Clavius, probably as a result of confusion around Clavius's use of the terms 'combinatio' and 'conjunctio', Hérigone is careful to use his own Latin and French terms for permutations and combinations in equivalent positions in the text of the *Cursus* and *Cours*. The same level of consistency can be seen with mathematical

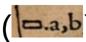
[83] Clavius investigates three questions in his digression on combinatorics: first, the combination without repetitions of two or more elements from a set of n elements; second, the total number of combinations without repetitions of two or more elements from a set of n elements; and third, the number of permutations of n elements.

rhetoric.[84] Rhetorical phrases used to link the text and persuade the reader are found throughout both texts. These include parts of speech used to link elements of his texts together, including 'ac proinde' and 'par consequent' [hence] (1634f: 36 and 138), 'itaque' and 'partant' [therefore] (1634f: 73, 110, and 122), 'quoniam' and 'or' [since] (1634f: 54), 'enim' and 'car' [for] (1634f: 54), 'videlicet' and 'à sçavoir' [namely] (1634f: 7, 17 and 159), and 'exempli gratia' and 'par exemple' [for example] (1634f: 32, 117, 153 and 155). Hérigone also uses linking phrases such as 'Demonstratio huis compendij erit perspicua' and 'La demonstration de ceste methode sera manifeste' [Demonstration of this method will be clear] (1634f: 76), and 'ut iam traditum est' and 'comme il a esté desia monstré' [as has already been shown] (1634f: 75), again ensuring equivalence in the two languages. These phrases are used by Hérigone in both languages to provide reassurance to non-expert readers, to help them understand the mathematical argument and convince them of its accuracy, as suggested by Kitcher (1995: 53). The effect of providing matching phrases in the two languages also serves to facilitate access to the Latin text for readers of the French version, in the manner suggested by Coldiron and discussed in section 3.2.

The mathematical nature of the text also means that much of it is written in the passive voice in both languages. The instructions and proofs for the four rules contain many examples such as 'subtrahuntur' and 'soient soustraits' [are subtracted] (1634f: 13) and 'Residuum addatur' and 'Soit adjousté le reste' [The remainder is added] (1634f: 16). It comes as a surprise, then, to find Hérigone occasionally using the first person, both plural and singular, and the second-person singular. When this happens, it gives a glimpse, albeit very guarded, of what I interpret as Hérigone's involvement with the textbook as a teacher, addressing the readers, his audience of students, which he does more directly in Latin than in French. Although in chapter VI he uses both the second-person singular and first-person plural in Latin — 'habebis quæsitum fractionem' [you will have the required fraction] and 'inveniemus' [we will find] (1634f: 68) — both are translated using the neutral third-person singular 'on' in French, suggesting a general subject. In a similar vein, when the first-person singular could be used, it is again replaced by the first-person plural in Latin ('notavimus iisdem

[84] 'Mathematical rhetoric' is used in this section in the sense defined in section 2.2.2, i.e. to describe how language is used in persuasive argumentation within mathematical communication.

letteris') and the impersonal third-person singular in French (on a marqué par mesmes lettres' [we have denoted with the same letters] (1634f: 96), or the first-person plural in both languages: 'ponimus' and 'nous supposons' [we postulate] (1634f: 101). It is only when presenting something potentially innovative — the work on memorisation techniques in chapter XVII — that Hérigone actually uses the first-person singular, in both languages, demonstrating his authority as the instigator of a new method: 'existimavi' and 'J'ay estimé' [I believed] (1634f: 136). Overall, the use of voices and the first person remains largely the same in both languages. This is part of the overwhelming similarity between the Latin and French texts in the chapter under consideration in particular and the *Cursus* as a whole. This level of similarity extends to the use of arithmetic signs in the text.[85]

In the Practical Arithmetic, Hérigone uses a combination of his own preferred signs and text to demonstrate arithmetical operations in both Latin and French. The signs are generally used in demonstrations with Hérigone's own symbols and abbreviations, as part of his new method, and so are common to both versions of the text. Addition is represented by the Christian cross on its side, in line with common practice at the time, with the longer side on the left (), while subtraction is represented by a more individual wavy line (). Hérigone often uses his own symbol '2/2' to stand for '=', while multiplication and division are represented respectively by a rectangle followed by a dot and the two numbers to be multiplied (), and the bilingual letter 'p' (for Latin 'per', or French 'par' [by]), with a line across its tail (). Although Hérigone has these symbols at his disposal, he does not always choose to use them in the text itself. For example, the terms 'signo ' and 'signo ' are used in Latin but translated as 'signe de plus' and 'signe de moins' [plus and minus sign] in discussion of the 'rule of two false positions' in chapter XIII (1634f: 106), perhaps indicating a lack of confidence on Hérigone's part with his French-reading audience's ability to deal with the symbols. Equality is often represented in both languages by the bilingual abbreviations 'snt' (for 'sunt' or 'sont' [are])

[85] The term 'arithmetic signs', as used in this discussion, signifies those symbols used increasingly by the majority of Early Modern mathematicians to represent equality and the four rules governing number operations in all languages. Discussion of the use of signs for these purposes can be found in section 2.2.4.

(1634f: 13), or ‘fa.’ (for ‘facit’ or ‘fait’ [make]) (1634f: 25) rather than the symbols given in the table of symbols and abbreviations.

It is clear from the information presented above that the mathematical terminology, rhetorical phrases and mathematical signs that make up a large part of the text are used to provide two largely equivalent texts with very few differences between them. While this is true throughout all aspects of the text, there are nevertheless a number of differences, mostly very small, some of which shed light on Hérigone’s approach to translation in the *Cursus*. As will be seen below, many of the differences between the two texts are minor: most are probably deliberate, but a few are simply errors, some clear-cut, others less so. The differences, whether deliberate or not, involve omissions, either of words or longer pieces of text, the use of synonyms, and a lack of consistency in choosing equivalent terms. In addition, on one occasion, Hérigone makes the decision to adapt an example he provides in the text.

The most obvious error occurs when Hérigone translates the fraction ‘duæ quintæ’ [two-fifths] as ‘deux tiers’ [two-thirds]; the bilingual working uses the fraction $\frac{2}{5}$, so this was clearly simply a transcription or printing error (1634f: 68). Most of the rest of the differences between the two texts cannot really be described as errors. Instead, they can be labelled as omissions and inconsistencies. This includes, for example, the omission of information in French that would allow the reader to answer a question: the information that three merchants in example 4 in chapter X pooled their money for ‘9 mensium’ [9 months] is missing from the French text, making it impossible to work out how much each one put in (1634f: 93–94).

Omissions, and sometimes additions of text, also occur when Hérigone uses pairs of synonyms or near-synonyms in either both or one of the languages. For example, when introducing fractions, he calls them ‘Fractio sive numerus fractus’ and ‘La fraction ou nombre rompu’ [Fraction or broken number] (1634f: 53).[86] Two Latin synonyms are occasionally translated by a single French word, as in the case of ‘examen sive probatio’ [examination or proof], which is translated by the single word ‘preuve’ [proof] (1634f: 13). It is

[86] Hauchecorne states that fractions were not originally conceived as numbers but as the result of breaking up whole numbers (hence ‘broken number’) (2003: 78).

not clear why Hérigone does this, as he more frequently uses ‘examen’ alone as the equivalent of ‘preuve’ in the book (1634f: 21 and 26, for example). On one occasion, however, he works the other way round, writing ‘probatio’ [proof] alone in Latin but translating it as ‘l’examen ou preuve’ in French (1634f: 20). There are other examples where Hérigone translates a Latin term by two French synonyms or near-synonyms, including the translation of ‘inversa’ by ‘inverse ou rebourse’ [inverse or reverse] (1634f: 81).

In addition to errors, omissions and additions, there are inconsistencies in translation between the two versions of the text. Two areas where this occurs most frequently are in the writing of numbers in digits and words and in the use of terminology related to the four arithmetical operations. There are a number of occasions when Hérigone uses a digit in Latin but words in French, as with ‘8 ulnæ’ translated as ‘huict aulnes’ [8/eight aulnes] (1634f: 71–72).[87] The tendency is frequently, though not exclusively, the other way round when it comes to dates, with numbers written in words in Latin and in numerals in French: ‘quarto Octobris’ is translated as ‘le 4 d’Octobre’ [4 October] (1634f: 143) for example. Hérigone is also inconsistent in his equivalent use of terms for the arithmetical operations. The most apparent is the French verb ‘multiplier’; Hérigone frequently avoids using ‘multiplico’ in Latin. Whereas he is happy to use ‘multiplicatio’ for ‘multiplication’ (1634f: 16, 19 and 21, for example), ‘multiplicandus’ for ‘à multiplier’ [to be multiplied] (1634f: 18), and ‘multiplicator’ [multiplier] (1634f: 18, 20 and 21, for example) on many occasions, he rarely uses the verb form: ‘multiplicentur’ [is multiplied] is an unusual case, translated by ‘il faudra multiplier’ [must be multiplied] (1634f: 18). Instead, he uses the verb ‘ducto’: for example, in the proof of division with whole numbers, he writes ‘5 ductus in 3, facit 15’ and ‘5 estant multiplié par 3 fait 15’ [5 multiplied by 3 makes 15] (1634f: 26), and in his note at the end of the proposition on multiplication of fractions he states ‘ducto in denominatorem suæ fractionis’, which he translates with ‘l’ayant multiplié par le denominateur de sa fraction’ [having multiplied by the denominator of its fraction] (1634f: 66). Hérigone occasionally uses other Latin words for the other basic operations too: for example, ‘ex producto detrahendi sunt 10’ [10 is removed from the product] is translated using ‘on doit soustraire 10 du produit’ [10 has to be subtracted from

[87] According to Randle Cotgrave’s bilingual dictionary of 1611, an ‘aulne’ was similar to an English ‘ell’ at around three feet eight inches, but varied in different parts of France (1611: unpaginated).

the product] (1634f: 146), while ‘adjoustez’ [add] is used as the equivalent of ‘collige’ [gather] (1634f: 147), ‘soit adjousté’ [are added] as the equivalent of ‘auctus’ [increased] (1634f: 149), and ‘adjoustant’ [adding] as the equivalent of ‘adhibito’ [extended] (1634f: 159).[88]

Just one passage in the text includes a change that is neither an error, an omission or an inconsistency: Hérigone is required to adapt his text by replacing a Latin cultural example with a French one. In chapter XVIII on ecclesiastical calculations, he provides mnemonics for remembering the day of the week of the first of each month (1634f: 150). This was part of a practice known as the Dominical (or Sunday) Letter, used to calculate the relationship between dates as the days changed from year to year, with a particular focus on dates in the Christian calendar, such as Easter Sunday (Zerubavel 1989: 62–63). In the fourth century of the common era, the Roman Catholic Church had adopted the practice of designating the days of the week by the letters A–G, replacing an older Roman practice of labelling the eight-day market week using the letters A–H (Zerubavel 1989: 63). The new practice meant that the first day of January was always designated as A, as was every other day in the year on the same day as 1 January. This also meant that the letters for the first day of the other months stayed constant (so, for example, 1 February was always a ‘D’ day) (Zerubavel 1989: 63–64).[89] A number of Latin mnemonics in the form of verses were invented to help people remember the letter for the first day of each month (Zerubavel 1989: 63–65), one of which is used by Hérigone in this chapter: ‘*Astra dabit Dominus, gratisque beabit egenos / Gratia Christicolæ feret aurea dona fideli*’ (1634f: 150). The meaning of the verse is less important than the initial letters of the twelve words, which provide the required letters for the days of the week of the first day of each month. As the meaning of the words themselves is of secondary importance, Hérigone replaces it in the French text with: ‘Adam d’un grand bien et grace fut au defaut’

[88] This is probably another example of the phenomenon noted above by Le Dividich that not all mathematical vocabulary was used in a settled, uniform manner in the seventeenth century. Although the terminology of the basic operations was available earlier, it was not widely used in mathematics until mathematical operations with the arabic numbers became more widespread in the late fifteenth and sixteen centuries, and the terminology surrounding them took longer to be accepted (Hauchecorne 2003: 15, 58, 192).

[89] 1 February was the thirty-second day of the year and $32 = 4 \times 7 + 4$. The remainder of 4 meant that it had to be labelled with the fourth letter of the alphabet, D; as 1 January was an ‘A’ day and D is three letters further on in the alphabet than A, 1 February was always three days later in the week than 1 January. The first day of each of the other months went in the sequence D, G, B, E, G, C, F, A, D, F.

(1634f: 150).[90] This is a verse where, instead of twelve words, '[l]es 12 syllabes [...] appartiennent aux 12 mois de l'année' [the 12 syllables (...) belong to the 12 months of the year] (1634f: 150). The purpose of adaptation is to 'create a new situation [in the target language culture] that can be considered as being equivalent' (Vinay and Darbelnet 2004: 135). This is what Hérigone has achieved with his creation, or use, of an equivalent religious verse where the initial letters of the Latin words have been replaced by the initial letters of the French syllables.

Despite the textual and linguistic difference highlighted by the final example above, examination of the Practical Arithmetic has shown that the Latin and French texts are very similar. At the mathematical level, the propositions, examples, and other features typically found in mathematical texts are handled the same way in both languages. Moreover, the mathematical terminology used in the book is largely well-established Latin and French vocabulary where, with the exception of some terms related to the four arithmetic operations, the vast majority of the French terms are cognates derived from their Latin equivalents. Similarly, the phrases of mathematical rhetoric that link the text are very similar in both versions. Other differences between the two texts are minor, consisting largely of clear errors, small omissions, and slight inconsistencies. A more significant difference occurs when Hérigone responds to difficulties posed by the need to find a cultural alternative to a Latin mnemonic, but this is not enough to create a significantly different text.

The findings as they relate to the Practical Arithmetic are therefore consistent with Krause's findings that the layout of modern *en face* editions, which is similar in many ways to the layout of the *Cursus* as a whole, demonstrates a high degree of equivalence between the two texts represented (2006: 2). The minor differences between the texts stand out because of their relative rarity, yet none is sufficiently significant to alter perceptions of the text; this will not be the case in chapters 4 and 5 of this thesis, where separate bilingual works by Mersenne and Pascal will be examined in detail and greater differences found. Indeed, the relative rarity of the differences is the most

[90] Note that it is the spelling of the Latin words and French syllables that is key, and not their pronunciation: for example, the letter for the beginning of August is 'C', which would have been pronounced [k] in 'Christicolæ', but [s] in the second syllable of 'grace'.

significant feature of the Practical Arithmetic and, by extension, the *Cursus*, as it is caused by the close equivalence between the vast majority of the two parallel texts.

3.5 Chapter conclusion

My investigation into the *Cursus* as a whole and my more detailed examination of specific aspects of the work have produced answers to the questions posed at the beginning of this chapter. It has become clear that Hérigone compiled the *Cursus* as a bilingual work in order to maximise his audience. As established in chapter 2, there were four distinct audiences for a work such as the *Cursus* when it was published. First, there existed within the Europe of the early seventeenth century a significant community of learned individuals that constituted an audience for a mathematical work containing a summary of all known mathematical knowledge, such as the *Cursus*. Increasing numbers of these scholars were also able to read the French version of the text as the language's influence grew, creating a second potential audience. Alongside this group were mathematicians who made up the membership of the new academies and who were comfortable reading and talking about mathematics in both Latin and French. Finally, there also existed within France an increasingly educated and cultivated elite that was eager to learn about and discuss mathematical topics of all kinds, in French alone, and which was probably responsible for the increasing number of mathematical works published in French at this time, including the summary version of the *Cursus* that is Hérigone's only other known published work. Reaching this non-specialist audience was the motivation behind Hérigone's new method of replacing verbal explanations and demonstrations by a range of symbols in the *Cursus*, a method that did not succeed in making the work trilingual: instead of replacing the two languages used in the self-translation, the symbols served to complement them.

The *Cursus*'s status as a textbook explains its *mise-en-page* as a bilingual text with text in both columnar and interlinear formats. Most bilingual works printed in this format were published for educational purposes, although generally as language aids. The *mise-en-page* suggests that Hérigone and his publisher may have had in mind linguistic as well as mathematical purposes when they designed the *Cursus* in this way: spacing equivalent text in clearly separated columns, for instance, as identified by Coldiron, is a clear indicator of such an intent. The layout also allows for conclusions to be drawn about the question of an ‘original’ version of the work. This chapter has shown that placement of the Latin text on the left identifies it as the probable original, authoritative version of the *Cursus*. This positioning of the original is complemented by its placement above the French text elsewhere in the *Cursus*. The use of roman type for the Latin and italics for the French version supports this view of the relationship between the versions of the *Cursus*, and Latin’s use as the sole language of the work’s dedication tends to confirm this view.

The existence of a Latin original suggests a process of consecutive self-translation from Latin to French rather than simultaneous composition in the two languages, but does not preclude simultaneous self-translation as a possibility. Whether the *Cursus* was created simultaneously or consecutively, detailed examination of parts of the two versions of the work in this chapter has shown that Hérigone took original work from other mathematicians along with long-standing mathematical knowledge, rewrote it so that the two versions of his work corresponded closely to each other, and provided demonstrations that could relate to either version of the text using his own new symbolic system. In this way, he established his authority as the rewriter and compiler of the assembled material and as the bilingual author of the *Cursus*.

The decision to place the Latin and French texts so close together meant that there was likely to be little difference between the texts, which is a known feature of translations printed in this way, the most likely reason being that proximity would highlight any differences more clearly than the publication of separate texts. This supposition was borne out by detailed examination of both the paratext and the Practical Arithmetic in the main text of volume two. Investigation of both parts of the text of the two versions of the *Cursus* demonstrated that the Latin and French texts correspond to a very high degree at the level of content, structure, terminology, phraseology, and use of voice and mathematical symbols. In both texts, too, Hérigone shows an awareness of rhetoric and its persuasive power. He uses the address to the reader in the first volume to introduce classical authorities to support his new method for mathematical demonstrations, supporting this appeal to authority with a chronology of mathematicians and their achievements in the sixth volume, a scholarly tradition to which he feels he also belongs. He further supports the clarity, brevity and intelligibility of his new method with the use of standard rhetorical techniques and persuades the readers of both texts of the correctness of his mathematical thinking with the support of phrases of mathematical rhetoric.

Rhetoric in both forms described above features in differences between the Latin and French versions of the *Cursus* as set out in this chapter. One difference between the texts is the strategic, formulaic flattery of Bassompierre, his patron, in the Latin-only dedication. A second is Hérigone's use of rhetoric to persuade the French-only readers of his fifth volume to keep persevering to the end of the work. The latter example is one of the very few differences between the versions of the text. Overall, the significant level of overlap between the *Cursus* and the *Cours* means that any differences between the two versions of the paratext and the main text tend to be amplified to a greater degree than they would be in separate volumes. My investigation into the paratexts suggests, for example, that Hérigone viewed the audiences for the two versions of the work in subtly different ways. He altered the paratext in small but significant ways to make it easier for the less specialised part of his French-speaking audiences to navigate the text, translating Greek references in the Latin text into French, adding everyday words to explain abstract terminology, and adding text to cajole, persuade and empathise with this audience. Most differences between the versions of the Practical Arithmetic, on the other hand, can be attributed to errors, simple omissions of words and phrases, and inconsistencies in translation of relatively minor details. The only other difference, an adaptation of the text, could more clearly be attributed to a desire on Hérigone's part to create an easy-to-read, culturally appropriate French translation of the Latin text. Although this was not the way in which Hérigone necessarily envisaged making the *Cursus* more accessible for the 'moins advancez' members of his readership in the address to the reader, it is likely to have been more successful than his new method for presenting demonstrations, few of the parts of which have endured.

Chapter 4

Marin Mersenne: the *Harmonie universelle* and *Harmonicorum libri*

The two versions of Marin Mersenne's bilingual musical work, the *Harmonie universelle* and *Harmonicorum libri*, represent the culmination of the author's research into music. Both versions of the work are made up of a series of books on a range of musical topics, many underpinned by mathematical theory: Mersenne had made it clear in the earlier, preparatory *Traité de l'harmonie universelle* (1627) that he believed that '[l]a Musique est une partie des Mathematiques, et par consequent une science' [Music is part of Mathematics and consequently a science] (1627: 2).[91] As I will show in the course of this chapter, the bilingual works were written and published together, but do not correspond closely in the same way as the versions of Hérigone's *Cursus mathematicus*: while they include a large amount of common content and are written in a similar style, there are significant differences in both the lengths of the works and their structures, and there is no direct correspondence between the texts. The existence of large-scale differences between the *Harmonie universelle* and *Harmonicorum libri* clearly has implications for the work as a self-translation, which I set out below. While research has been conducted into the music and mathematics in the two versions of the work, they have never been studied from a self-translation perspective, despite the fact that '[n]o one knows to what extent [the] *Harmonie universelle* and the *Harmonicorum libri* run parallel' (Cohen 1984: 99). My research is intended to fill that gap in knowledge: I will investigate the similarities and differences between the *Harmonie universelle* and *Harmonicorum libri* as twin texts on the subject of music. I will begin by considering the relationship between them at the level of the whole work before going on to examine parallel books from the two versions in greater detail.

The similarities and differences between the *Harmonie universelle* and *Harmonicorum libri* noted above give rise to a series of questions about Mersenne's reasons for writing his musical work in two bilingual versions and about the methods he used to do so. With regard to motivation, the most

[91] And, as Daniel Garber reminds us in his discussion of the subject matter of the *Harmonie universelle*, 'music [is], of course, a traditional branch of mixed mathematics' (2004: 144). A fuller clarification of a seventeenth-century understanding of 'mathematics', including 'mixed mathematics', can be found in the 'Definitions and editorial principles' section at the beginning of the thesis.

important question is clearly: why did Mersenne produce the *Harmonie universelle* and *Harmonicorum libri* as a bilingual work? This prompts another question: how did the *Harmonie universelle* and *Harmonicorum libri* fit into the writing practice and language choices evident in Mersenne's work as a whole? To answer these initial questions, I will begin in section 4.1 by examining the relevant features of Mersenne's life and writing, particularly his background in science and mathematics. This will allow me to place his scholarly activity and his works within the wider context of early seventeenth-century French scientific writing. In so doing, I will focus particularly on the languages Mersenne used in his writing, against the background of the knowledge about language trends in mathematical publishing in the seventeenth century, as outlined in chapter 2.

These questions give rise to further questions that are more directly related to the *Harmonie universelle* and *Harmonicorum libri*: if Mersenne wrote the two works together and used similar material in both, can either version be considered the original? How similar and how different are they? Can their relationship be described as self-translation in the sense of translation from one version to another or as two versions of a bilingual work? To answer these questions, I will compare the two versions of the work in section 4.2. The section will begin with a general introduction to their creation, followed by a comparative analysis of their structures. The vast amount of content on a number of topics covered in the two versions of the musical work, particularly the *Harmonie universelle*, means that a detailed comparison of Mersenne's writing practice would not be practical at the level of the works as a whole for a case study of this nature and length.[92] For that reason the next set of questions will be investigated, in section 4.3, at the level of sections of individual books within the larger works. The books I will examine and compare are the *Livre second des chants* [Second Book on Songs] from the *Harmonie universelle* and the *Liber septimus de cantibus* [Seventh Book on Songs] from the *Harmonicorum libri*. I have chosen these books in particular because of their mathematical content: together they form the most important source of Mersenne's work on combinatorics, the mathematical topic that links the three case studies in this thesis. Although the two books have been selected because of their common subject matter (songs), the comparison between them will

[92] As mentioned above, the *Harmonie universelle* consists of 1448 pages in total.

focus on all aspects of Mersenne's written practice in describing combinatorics, to enable me to answer a number of further questions, including: what does a comparison of his treatment of combinatorics in the two books reveal about Mersenne's writing practice? How similar and how different is his treatment of combinatorics in the two books? Is it structured in the same way in the two books? The answers to these questions will bring the discussion back to some of the questions raised above: are the two books both original versions of a book on songs or is one the original and the other a translation? And does this have any implications for the relationship between the full works to which they belong?

4.1 Mersenne: life and works

4.1.1 Collaboration and the new science

Mersenne was a Minim friar who is probably best known as the 'secrétaire général de l'Europe savant' [general secretary of scholarly Europe] (Lenoble 1948: 54). In the opinion of Hans Bots, it was Mersenne's work in creating a scientific community, both in France and across Europe, that was his greatest contribution to the development of science, rather than any original contributions he might have made himself (2005: 180–81). There were a number of dimensions to Mersenne's role in creating such a community: he created a mathematical academy in Paris, as noted in chapter 2, corresponded with many of the most notable mathematicians of his time, and collaborated with, and promoted the work of, a number of fellow scholars. All of this work was underpinned by his contribution as a champion of the new 'mechanical' approach to science that emerged in the first half of the seventeenth century.

Having spent his early life as a monk moving around France, Mersenne settled at the Minim convent of l'Annonciade in Paris in 1619 and spent the rest of his life there, benefitting from an atmosphere where his scientific work and his extensive networking were encouraged (Bots 2005: 165). In addition, according to Samuel Hartlib (c. 1600–62), an English educational reformer and fellow 'intelligencer' in the Republic of Letters, Mersenne benefitted from a well-educated support system within the convent (Pal 2018: 144; Blair 2014d).[93] When he arrived in Paris in 1619, Mersenne found a city where scholars from all disciplines met in cabinets to discuss the latest ideas in mathematics, music, astronomy, physics and a range of other disciplines (Fletcher 1996: 148). He attended a number of the cabinets, including the renowned group organised by the brothers Dupuy (Sturdy 1995: 14).[94] Using what he had learned from the groups he attended, Mersenne began organising his own informal meetings to discuss mathematics in his rooms at the convent. From the mid-1630s, these meetings turned into the more formal *Academia Parisiensis* [Parisian Academy], the members of which were responsible for highly innovative scientific and mathematical work, including research into the vacuum, analyses of conic sections, and other applications of arithmetic and geometry to physical processes that were not part of the university curriculum (Grosslight 2013: 337). As a result, Mersenne's academy was the most prestigious of the unofficial science societies that provided the template for the creation of the *Académie des sciences* [French Academy of Science] in 1666 (Mesnard 1991b: 241).

At the same time that Mersenne was establishing his informal academy, he began corresponding with scholars all over Europe, particularly, but not exclusively, with mathematicians, building up a network of contacts with the most eminent scholars of the day and putting many in contact with each other, in much the same way that the meetings at the convent were designed to enable mathematicians to meet and discuss the most significant contemporary topics (Fletcher 1996: 147). He also sought to popularise the work of many of the mathematicians with whom he was in contact, both correspondents and members of his academy.[95] As well as including Roberval's *Traité de mechanique* in the *Harmonie universelle*, Mersenne also collaborated with its author in a number of other areas of mathematics, including the cycloid and

---

[93] In his *Ephemerides* of 1639, Hartlib compares his own situation with a number of other intelligencers, stating that Mersenne had 'the whole Cloister maintaining the charges', i.e. bearing the load (quoted in Pal 2018: 144).
[94] As discussed in section 2.3.2.
[95] Mersenne used a number of his musical and mathematical works to promote the work of other authors. The *Questions harmoniques* [Questions on Harmony] includes the *Discours sceptique sur la musique* [Sceptical Discourse on Music] of François de La Mothe Le Vayer (1588–1672), the unpublished *Livre de la nature des sons* [Book on the Nature of Sounds] contains a French translation of Bacon's work on music, and Gilles Personne de Roberval's *Traité de mechanique* [Treatise on Mechanics] can be found in the *Harmonie universelle* (Fabbri 2007: 292–93). He also published work on optics by Walter Warner (1563–1643) and Hobbes in his *Cogitata physico-mathematica* [Physico-Mathematic Thoughts] (Jacquot and Jones 1973: 14). In addition, Mersenne was the first to translate and publish Galileo's work in France (Martin 1969: I, 247).

tangents to curves (Beaulieu 1989 : 180–81). Mersenne seems to have seen his mission as ‘chercher des moyens pour améliorer la transmission du savoir’ [to find ways of improving the transmission of knowledge] (Bots 2005: 174) by means of networking and collaboration, in the spirit of the Republic of Letters, as outlined in chapter 2. His own work, the academy, his correspondence and the promotion of the work of other scholars were complementary means of achieving this aim.

As a result of his organisational work, Mersenne found himself at the centre of two of the strands that transformed the study of science in the first half of the seventeenth century: what Cohen refers to on the one hand as ‘the beginnings of an ongoing process of mathematization of nature experimentally sustained’ involving the remodelling of the mathematical portion of classical knowledge as enriched by Islamic civilisation and Renaissance Europe, the main features of which were recounted in section 2.2.1, and on the other as ‘a fact-finding, practice-oriented mode of experimental science’ (2010: xvi).[96] Alistair Crombie believes that Mersenne’s main aim in promoting a rational scientific approach was to use it to find and demonstrate the truth in order to combat a range of sceptics, mystics and others who he felt presented a danger to Christianity (1981: 316). Mathematics was particularly applicable to this mission. As Robert Lenoble has pointed out, for Mersenne, ‘[l]es mathématiques [...] représentent le type de la certitude [...]. Il écrit en 1625 que la géométrie analytique serait le meilleur moyen de construire une science capable de décourager tous les sceptiques’ [mathematics (…) represented a kind of certainty (…). He wrote in 1625 that analytical geometry would be the best means of constructing a science capable of discouraging all of the sceptics] (1943: 452).

Of all the scientific topics on which he worked during his lifetime, ‘music was perhaps the science that most deeply and continuously interested Mersenne’ (Malet and Cozzoli 2010: 3). Certainly, the largest part of the research he conducted was devoted to various aspects of music (Fabbri 2007: 288). This was a deliberate and rational choice. In *Les Préludes de l'harmonie universelle, ou Questions curieuses* [Introduction to Universal Harmony, or

[96] As noted in the introduction, the notions of a seventeenth-century ‘Scientific Revolution’ and an associated ‘mathematisation of learning’ are the subject of debate within the history of ideas. Footnote 2 includes references for a summary of the key arguments.

Interesting Questions] (1634), Mersenne explained that there was not enough time available for anyone to study every science in depth (1634: 136), and that the solution would be if ‘l’on s’appliquait à la partie que l’on affectionne le plus’ [one applied oneself to the part for which one has the greatest passion] (1634: 137). He describes music as the science that ‘j’ay particulierement embrassée’ [I have embraced in particular] (1634: 139). It is clear who Mersenne identified as his scholarly antecedents: he had previously invoked Plato (*c.* 428–348 BCE) and Pythagoras (*c.* 570–*c.* 500 BCE) in the dedication and preface of the *Traité de l'harmonie universelle* [Treatise on Universal Harmony] (1627).

In addition, as I will show in the next section, Peter Dear has demonstrated that Mersenne’s concept of ‘universal harmony’ was informed by the writings of St. Augustine of Hippo (354–430 CE) (1988: 97–98). Mersenne’s pursuit of harmony through the mathematisation of music followed closely on similar work by German astronomer Johannes Kepler (1571–1630). According to Owen Gingerich, ‘Kepler’s scientific thought was characterized by his profound sense of order and harmony, which was intimately linked with his theological view of God the Creator’ (1981: 307). Kepler’s work on harmony was informed by his belief that the physical universe could be explained by mechanical principles (Gingerich 1981: 307). Mersenne took a similar approach to music, using the methods of rationalist enquiry he was advocating for science and mathematics to explore music in depth (Bavington 2012: 14). He eventually rejected much of Kepler’s work on harmony (Buzon 1994: 123), but kept the idea of universal harmony for the title of his major work on music (Lenoble 1943: 531). The result was what Cohen has called ‘the first full-fledged application of the experimental method to the science of music’ (1984: 114).

The brief summary of Mersenne’s intellectual life given above provides an indication of the major areas of intellectual interest that occupied him throughout his life: his first published works were generally theological, dealing with those beliefs that Mersenne felt presented a danger to Christianity; he followed this with publication of a range of scientific works, dealing with mathematics, natural philosophy, and music (Lenoble 1943: 13; Dear 1988: 4; Bavington 2012: 13).

4.1.2 Mersenne's published works and choice of language

Mersenne's published works fall approximately into four categories: writings on religious topics, mostly composed in the 1620s and early 1630s; physico-mathematical works published throughout his active scholarly life from the 1620s until his death in 1648 and, in one case, posthumously in the early 1650s; writings on natural philosophy in the 1630s; and musical writings, published in the 1620s and 1630s. It is likely that Mersenne would not have divided his work up in this way and, in truth, it is difficult to make clear-cut distinctions between types of works: Lenoble sees his works as an evolving demonstration of Mersenne's desire to demonstrate the mutual relationship between religion and science, a 'syncrétisme scientifico-religieux qui fait le fond de la pensée du Minime' [a syncretism of science and religion that forms the basis of the Minim's thinking] (1943: 13, 34). I have nevertheless distinguished between types of works, using a modern perspective, in order to analyse the languages used in different genres. As I will show in this section, some works in each of the four approximate categories into which I have divided Mersenne's works were written in Latin and others in French, while the *Harmonie universelle* and *Harmonicorum libri* constitute the only instance of bilingual versions of the same text. Mersenne was also a prolific correspondent, his collected letters in both Latin and French taking up seventeen volumes (Mersenne 1932–88).

The majority of Mersenne's early religious works — including *L'Usage de la raison* [The Use of Reason] (1623), *L'Analyse de la vie spirituelle* [Analysis of the Spiritual Life] (1623), both of which are now unavailable (Lenoble 1943: 25), *L'Impiété des déistes, athées et libertins de ce temps* [The Ungodliness of the Deists, Atheists and Libertines of this Age] (1624), and *La Vérité des sciences: Contre les sceptiques ou Pyrrhoniens* [The Truth of Science: Against the Sceptics or Pyrrhonians] (1625) — were written in French, the only major exception being the *Quæstiones celeberrimæ in Genesim* [Well-Known Questions in Genesis] and *Observationes, et emendationes ad Francisci Georgii Veneti problemata* [Observations, and Emendations to the Problems of Francisco Giorgio Veneto], which were published together in 1623 (Lenoble 1943: 25). The religious books were part of a trend identified by Martin: increasing numbers of books seeking to defend the established church against 'libertins' or free-thinkers were published between 1580 and 1635, peaking in the 1620s (1969: I, 176–77). The *Quæstiones in Genesim* was ‘a defence of orthodox theology and the rationality of nature against their enemies’ that included attacks on a number of European thinkers (Crombie 1994: II, 811), which partly explains why it was written in Latin. The other principal reason was its wide range of subject matter, ranging from theology, philosophy, medicine and law to mathematics, music, astronomy, physics and catoptrics, and aimed at a more widespread European scholarly audience (Lenoble 1943: 26, 43–44).

By contrast to his religious works, Mersenne’s mathematical books were mainly published in Latin. These works included the *Synopsis mathematica* [Mathematical Synopsis] (1626), ‘a collection of ancient and modern mathematical texts illustrating the rationality of nature and of natural science’ (Crombie 1994: II, 812), mainly consisting of the works of Euclid, Apollonius, Archimedes and others, as reconstituted by Maurolico in the mid-sixteenth century, along with some of Maurolico’s own work (Lenoble 1943: 33). The collection also included Mersenne’s own commentaries, written in an accessible style in an attempt to popularise the content (Sergescu 1948: 7). The other works in Latin were collections of modern and classical mathematics that included some of Mersenne’s own mathematical research: the *Universæ geometriæ, mixtæ mathematicæ synopsis* [Synopsis of Universal Geometry and Mixed Mathematics] (1644), which was an updated version of the *Synopsis mathematica*, the *Cogitata physico-mathematica* (1644), the *Novarum observationum physico-mathematicorum* [New Physico-Mathematic Observations] (1647), and the brief *Liber novus prælusorius* [New Introductory Book] (1648). The only later mathematical book published in French was the posthumous *L'Optique et la catoptrique* (1651), which appeared in the same volume as an edition of Niceron’s *La Perspective curieuse* (Lenoble 1943: xxx).

Crombie believes that, by the early 1630s, Mersenne ‘had begun to organize his style of writing [...] into a more systematically scientific natural philosophy’ (1994: II, 814). He presented his more systematic thinking in a range of works, mostly published in French: *Questions inouïes, ou récréations des savants* [Extraordinary Questions, or Recreation for Scholars] (1634) and *Questions théologiques, physiques, morales, et mathématiques* [Theological, Physical, Moral and Mathematical Questions] (1634), the *Traité des mouvements et de la chute des corps pesants* [Treatise on the Movements and

Falling of Heavy Bodies] (1634), a work dealing with Galileo's ideas on gravity and falling bodies, and *Les Mécaniques de Galilée* [Galileo's Mechanics] (1634) and *Les Nouvelles pensées de Galilée* [The New Thoughts of Galileo] (1639), described by Garber as paraphrases and adaptations of Galileo's work, accompanied by 'Mersenne's expansions and commentaries' (2004: 144). The purpose of these works was to popularise a range of important scientific ideas (Lenoble 1943: 39), hence the use of French.

Crombie also sees Mersenne's musical works as part of his 'mature natural philosophy' (1994: II, 814). Unlike the mathematical works, and in common with the religious works of the 1620s and the works of the 1630s, the majority of Mersenne's musical works were published in French — the *Traité de l'harmonie universelle*, the *Questions harmoniques* (1634), the *Les Préludes de l'harmonie universelle*, and the *Harmonie universelle* (1636–37). One of Mersenne's few unpublished works — the *Livre de la nature des sons* — dealt with music and was also written in French. In fact, the *Harmonicorum libri* (including the *Harmonicorum instrumentorum libri IV*) was Mersenne's only musical work to be published in Latin, and the *Harmonie universelle* and *Harmonicorum libri* was the only bilingual pair of works published by Mersenne.[97] Despite appearances, however, the *Harmonicorum libri* was not the only Latin work to contain Mersenne's work on music. As Crombie has noted, '[h]is first original contributions to acoustics [...], as well as analyses of ancient and modern musical theory [...], appeared in *Quæstiones in Genesim*' (1981: 319). And, after publication of the *Harmonie universelle* and *Harmonicorum libri*, Mersenne continued to write about acoustics in Latin in his three mathematical works in the 1640s (Crombie 1981: 319).

This account of Mersenne's published and unpublished works indicates two trends in his choice of language, one based on the subject matter of the works and their likely audience, the other on the date of publication. Most of the works were published in French, particularly the religious, philosophical and musical works, while the opposite was true for mathematics. It is also apparent that the works published in Latin were those that were most clearly aimed at a

[97] Mersenne was not the first seventeenth-century writer of a musical treatise to write in both Latin and the vernacular: German musicologist Michael Praetorius (1571–1621) showed a similar awareness of his audience as Mersenne, writing the first, more learned volume of his *Syntagma musicum* [Musical Collection] (1614–20) in Latin for a scholarly audience before switching to German for subsequent more practical volumes for a local audience (Bianchi 2015: 168).

wider scholarly audience in the Republic of Letters, spread across Europe, and that this was mainly true of the mathematical books.[98] The Latin works included the *Quæstiones in Genesim*, the *Harmonicorum libri,* the *Synopsis mathematica* and the three later mathematical books. The date of publication of these last three works (the 1640s) points to the second trend. As can be seen in appendix 1, the religious and musical works were mainly published in the 1620s and 1630s, which were the decades in the period surveyed (1610 to 1665) during which greater numbers of mathematics books were published in French than in Latin.[99] As noted in chapter 2, the first half of the seventeenth century saw a decline in the publication of scientific books of all kinds in Latin across Europe in general (Fransen 2017b: 629). There is every reason to suppose that Mersenne's choice of languages reflected this trend, at least in part. In contrast to the changes in scientific publishing as a whole, however, appendix 1 shows that Latin again began to rival French within mathematical works in the 1640s, a trend to which many of Mersenne's later mathematical works belonged.

Mersenne's choice of languages for his works seems to have been practical, focused on his audience. There is no evidence that he felt either language was superior to the other. In fact, according to Lenoble, he was of the view that all languages had their own merits and opposed those who believed that French was superior to Latin and Greek (1943: 518–19). Mersenne's use of language in his other works therefore prompts an important question: as the *Harmonie universelle* and *Harmonicorum libri* were written and published in the 1630s, when the vast majority of Mersenne's output was published in French, and the *Harmonicorum libri* was the only one of his musical works to be published in Latin, why did Mersenne create two versions of this work, one in French and the other in Latin, and at this time? I will investigate this and other

[98] Mersenne's appreciation of audience can also be seen in his correspondence. A brief analysis of the letters Mersenne wrote to his principal correspondents, based on metadata provided by Early Modern Letters Online [EMLO] (Cultures of Knowledge 2014), shows that his choice of language in his letter-writing was largely influenced by the identity of the correspondent. Justin Grosslight believes that, '[w]henever possible, Mersenne opted for vernacular correspondence' (2013: 338). In the main, therefore, he used French when writing to French scholars such as his patron, Nicolas-Claude Fabri de Peiresc (1580–1637), and French theologians such as André Rivet (1572–1651), and when corresponding with foreign scholars who had spent time in Paris and who he knew were confident in French, including Haak and the Dutch scholars Constantijn and Christiaan Huygens. Mersenne used Latin in his letters to foreign scholars who were likely to have little or no French, including the Italian physicists and mathematicians Evangelista Torricelli (1608–1647) and Galileo, the Polish astronomer Johannes Hevelius (1611–1687), and English mathematician Pell. The letters in both languages also contained passages in Hebrew and Ancient Greek, and the letters in French contained passages in Latin, in both cases presumably because Mersenne expected his learned correspondents to understand the references.

[99] The number of books published in each language in each decade can be found in table 15 of appendix 1, section A.

related questions in the next section. I will begin by examining the parallel genesis of the *Harmonie universelle* and *Harmonicorum libri*, before going on to investigate the relationship between the finished works.

4.2 The *Harmonie universelle* and *Harmonicorum libri*

4.2.1 Creating the *Harmonie universelle* and *Harmonicorum libri*

Armand Beaulieu describes the *Harmonie universelle* and *Harmonicorum libri* as the realisation of a project to investigate music from a scientific perspective (1995: 134). That was certainly one important aspect of Mersenne purpose in creating the works. However, they can only fully be understood as the culmination of Mersenne's systematic attempt to fuse science and religion in order to overcome irrational belief systems, as discussed in the previous section. At the heart of Mersenne's great passion for music was the concept of 'universal harmony' found in the title of the French book. Mersenne saw music as the purveyor of harmony, 'la panacée de tous les maux de l'âme et du corps' [the panacea for all the ills of the soul and the body] (Lenoble 1943: 531). The Greeks had thought that music was capable of turning human souls towards virtue or vice; Mersenne's aim was to produce a work that would help humanity choose virtue (Lenoble 1943: 526). Dear argues convincingly that, for Mersenne, the notion 'represented the divine wisdom ordering creation' (1988: 140). In the dedication to the *Traité de l'harmonie universelle*, Mersenne reminds the reader that Plato and Pythagoras had attributed the creation of music to God as a means of saving human souls (1627: unnumbered). Pythagoras is believed to have been the first to realise that, when the lengths of vibrating strings are expressed as the ratios of whole numbers, the tones produced are harmonious (Merzbach and Boyer 2010: 50). This discovery was extrapolated to the concept of the 'harmony of the spheres', according to which the heavenly bodies also emit harmonious tones as they move through space (Merzbach and Boyer 2010: 50). The notion of world harmony was popular amongst mediaeval Christian thinkers, including St. Augustine (Weber 1976: 76–77). Augustine believed that God had ordered the universe mathematically and that the mathematics within music meant that music and harmony represented the highest manifestation of divine wisdom (Dear 1988: 107–08). Augustine's thinking provided the philosophical justification for Mersenne's concept of universal harmony based on abstract mathematical relationships such as the perfect nature of ratios provided by God (Dear 1988: 79, 98, 108).

Mersenne developed his thinking on music over a long period of time, making his first original contributions to music in the field of acoustics in *Quæstiones in Genesim* in 1623 (Crombie 1981: 319) where he also mentioned his plans for a major work on music for the first time. Two years later, in *La Vérité des sciences*, he announced ‘le grand œuvre de la Musique’ [the great work on Music] that would become the *Harmonie universelle* and *Harmonicorum libri* (Mersenne 1625: 567). This project ‘henceforth became his chief intellectual preoccupation’ (Crombie 1981: 319). Early outlines of the *Harmonie universelle* and *Harmonicorum libri* appeared in the three French works on music that preceded them: the *Traité de l’harmonie universelle*, the *Questions harmoniques*, and *Les Préludes de l’harmonie universelle* (Crombie 1981: 319).

The first of the works on music, the *Traité de l’harmonie universelle*, was written shortly before Mersenne obtained the *privilèges du roi* for the *Harmonie universelle* and *Harmonicorum libri*, in October 1629 (Mersenne 1636a: xii; 1965a: xvi). In a summary placed at the beginning of this early treatise, Mersenne described a sixteen-book work intended to cover a range of topics, including musical types and definitions, the nature of sounds, the voice and sound-producing bodies, consonance and dissonance, composition, rhythm and metre, musical instruments, music’s use for philosophers, theologians, astrologers and others, and the place of harmony in theology, moral philosophy, and heaven’ (1627: unpaginated). The two books of the *Traité de l’harmonie universelle* were originally intended as the first two books of the sixteen planned for the longer work. Mersenne almost certainly began writing the remainder of the *Harmonie universelle* and *Harmonicorum libri* soon after publication of the early treatise and immediately after receiving the *privilèges* (Crombie 1981: 319).

In writing the two works, Mersenne kept only approximately to his original plan, however. The final version of the *Harmonicorum libri* consisted of twelve books — eight in the *Harmonicorum libri VIII* and four in the *Harmonicorum instrumentorum libri IV* — and ‘covered a set of topics which corresponded only approximately to the remaining 14 books of the original plan' (Wardhaugh 2017: 23). The *Harmonie universelle* diverged even more from the initial design, consisting of nineteen books in total collected into four treatises, each of which has its own dedication and preface, plus two additional works, one by Mersenne and one by Roberval.[100] The numbering of the treatises restarts with each new treatise, so there are four books named *Livre premier*, for example.[101]

Mersenne would have liked to create an even longer work: in a letter dated 17 November 1635, he informed Peiresc about constraints on production of the Latin books on instruments: 'Si j'eusse eu affaire à un libraire un peu plus accommodé, j'eusse peu grossir ces livres de moitié, mais n'ayant pas eu moyen de faire de plus grands frais, il m'a fallu raccourcir mes escrits à ses facultez' [If I had been dealing with a printer-bookseller of greater means, I would have been able to increase these books by half again but, not having the means to pay higher costs, I have had to abridge my writing to his capacities] (Mersenne 1959c: 477).[102]

It is clear from Mersenne's correspondence in 1633 and 1634 that the *Harmonie universelle* and *Harmonicorum libri* were written simultaneously (Crombie 1994: II, 871). In 1634, Mersenne told Peiresc that he had completed the two works and that they had taken up ten years of his life (1955: 81), an effort described in the 'Extraict du privilege du roi' as 'un long travail' (1965a: xvi). The two works were printed separately, by different printers (Lesure 1965: vii). It is not clear why the same printer did not handle both works; perhaps the length of the *Harmonie universelle* and the risk represented by Mersenne's lack of funds were contributory factors. The musical examples, which were largely the same in the two versions, were all type-set by Pierre Ballard (*c.* 1577–1639) (Guillo 2003: II, 291). According to François Lesure, he was the 'seul

[100] Full details of the structure of both works can be found in appendix 5.
[101] The *Livre de l'utilité de l'harmonie* is the only book apparently without a number, although it is referred to as the *8. Livre de l'utilité de l'harmonie*, i.e. the eighth book in the *Traité des instrumens a chordes*, by Mersenne in the 'Table des propositions' that precedes the first treatise (1965a: xlvi).
[102] Peiresc was an astronomer, who, like Mersenne, corresponded with a wide range of scholars involved in the new mechanical philosophy (Sarasohn 1993: 79). He was also a patron to large numbers of his fellow scholars, providing them with funds, materials and introductions and access to each other and the libraries of France and Italy (Sarasohn 1993: 70). Peiresc provided Mersenne with books and contacts to research works including the *Harmonie universelle* and *Harmonicorum libri*, and money to have the works published (Sarasohn 1993: 79). Peiresc introduced Mersenne to Gassendi, the Italian musicologist Giovanni Battista Doni (1594–1647), and the papal Barberini family in Rome, for example, all of whom proved useful in researching Mersenne's musical works (Grosslight 2013: 343). As a result of his patronage, Mersenne dedicated the first published volume of the *Harmonie universelle*, the *Traitez des consonances, des dissonances, et de la composition*, and the *Harmonicorum instrumentorum libri IV* to Peiresc.

possesseur des caractères de musique' [the only person who had musical print type] (1965: v). The *Harmonicorum libri* and the *Harmonicorum instrumentorum libri IV* were initially published in 1635 and 1636 by Guillaume Baudry (born 1590s) as two separate works, with their own title pages and dedications (Guillo 2003: II, 291).[103] They were also published as a single work for the first time in 1636 by Baudry, with the title page and the paratext of the *Harmonicorum instrumentorum libri IV* omitted. The two works were reissued as a single volume in 1648 by Baudry and in 1652 by Thomas Jolly (died 1694), with only minor amendments, and entitled the *Harmonicorum libri XII* (Guillo 2003: II, 291).

Printing of the *Harmonie universelle* was a more drawn-out affair, taking over three years (Lesure 1965: v). The delays were caused by a number of factors, including Ballard's refusal to print the full work because of Mersenne's lack of funds, and the printer's slowness in type-setting the musical notation (Lesure 1965: vi). Following Ballard's refusal, the *privilège* for the work was given to Sébastien Cramoisy (1584–1669) (Lesure 1965: vi).[104] Progress was still slow, however, due to Mersenne's financial situation; in order to provide funds to accelerate matters, a number of the individual books within the *Harmonie universelle* were published in 1635 (Guillo 2003: II, 301).[105] The full version of the work was then printed in two volumes, the first appearing in 1636 and the second in 1637 (Guillo 2003: II, 296–99).[106]

What does the history of the creation and publication of the *Harmonie universelle* and *Harmonicorum libri* tell us about the relationship between the two versions? Mersenne applied for, and was given, *privilèges* for both works on the same day, as can be seen from the printed extracts of the *privilèges* in the completed works. The *privilèges* describe the *Harmonie universelle* and *Harmonicorum libri* as 'les livres intitulés *Harmonica*, tant en François qu'en Latin' and 'Libri Harmonicorum, tam Latine quam Gallice' [the books called

[103] The '*Privilège du roy* (*Diploma Regium*)' in the *Harmonicorum libri* states that it was assigned to Baudry by Mersenne on 7 September 1635.
[104] Cramoisy is described by Lesure as the King's printer under Richelieu's protection (1965: vi).
[105] Laurent Guillo lists fourteen of the books in the *Harmonie universelle* as printed separately by 1635, each with its own title page (2003: II, 301). Lenoble notes that the *Traitez de la nature des sons, et des mouvements* was originally printed as a separate work as early as November 1633 (1943: xxi)
[106] Although Cramoisy held the *privilège* for the *Harmonie universelle*, Guillo has identified copies where the publisher is identified as Ballard or Richard Charlemagne, the latter a little-known printer (2003: II, 301). According to Lesure, it is likely that Ballard and Charlemagne purchased copies for resale and added title pages of their own (1965: vii, note 5).

Harmonics in both Latin and French] (1636a: xii; 1965a: xvi). Mersenne had already described them, in 1623, as his 'grand œuvre de la Musique', implying he viewed them as a single great work on music. This suggests that, when he conceived them, Mersenne viewed the works as two versions of the same book. This hypothesis is supported by the writing and publication process: the two versions were written alongside each other, completed at the same time, and published around the same time, albeit by different publishers. Moreover, they contained similar content and shared many of the same diagrams and musical examples. As such, they are examples of Grutman's 'simultaneous self-translations' as defined in chapter 1 (2009a: 259). This shared history suggests that neither the *Harmonie universelle* nor the *Harmonicorum libri* can be considered the original version but that they should instead be viewed as dual original works. This matches Crombie's view: he describes the *Harmonicorum libri* and *Harmonie universelle* as 'two sets of treatises', written simultaneously, 'which *together* form [Mersenne's] great systematic work' (1981: 319).[107]

4.2.2 Comparing the *Harmonie universelle* and *Harmonicorum libri*

If Mersenne's practice in creating the *Harmonie universelle* and *Harmonicorum libri* suggests that the two works should be considered as dual original works that form one 'great systematic work', can the same conclusion be drawn with respect to the finished work? The most obvious starting point is Mersenne's own description of the relationship between the two works, provided in a letter he wrote to Peiresc on 12 October 1635, following completion of the works. In it he stated:

> J'ay fait un *Compendium* latin de la Musique françoise pour les estrangers, lequel j'essayray de vous envoyer par la premiere commodité, si toutesfois vous le desirez voir, après le françois, bien plus ample, plus correct et plus digne de vous, si je ne me trompe
>
> [I have created a Latin *Compendium* of French music for foreigners — a copy of which I will attempt to send you as soon as is convenient, if you would like to see one — based on the French version, which is much more comprehensive, more suitable and, if I am not mistaken, more worthy of you] (Mersenne 1959b: 423).

[107] The italics are mine and have been added for emphasis.

This summary of the relationship between the two completed versions leads to three observations. First, it shows clearly that Mersenne wrote the *Harmonie universelle* and *Harmonicorum libri* for different, clearly demarcated audiences: the '*Compendium* latin' for the 'estrangers', the non-French-speaking scholars in the Republic of Letters, and the French version for a French audience or audiences.[108] This matches the practice of writing for different audiences in Mersenne's complete works noted in section 4.1.2 above. Second, the extract from the letter suggests that, on completion, Mersenne considered the *Harmonicorum libri* to be 'après' the *Harmonie universelle*: based on the French text, but not a translation of it. As Lenoble notes: 'Il ne faut pas voir dans l'une de ces rédactions une traduction de l'autre, comme on le fait parfois par erreur' [Neither of these texts should be seen as a translation of the other, as is sometimes mistakenly the case] (1943: xxi). Mersenne's use of the word 'après' raises a third point: it implies that he saw the *Harmonicorum libri* as a secondary version of a French original. Both Lesure and Guillo note, however, that the *Harmonicorum libri* contains material that cannot be found in the *Harmonie universelle* (Lesure 1965: vii; Guillo 2003: II, 291). The presence of original material in the *Harmonicorum libri* suggests that it cannot be considered as a non-original text. Instead, it implies a more complex relationship, in keeping with my hypothesis above.

The foundation for Mersenne's assessment of the relationship between the *Harmonie universelle* and *Harmonicorum libri* is the 'bien plus ample' [much more comprehensive] nature of the *Harmonie universelle* and the description of the *Harmonicorum libri* as a 'compendium', or summary version. His view is shared by most scholars: both Lesure and Guillo describe the *Harmonicorum libri* as a 'condensé' [summary version] of the *Harmonie universelle* (Lesure 1965: vii; Guillo 2003: II, 291), while Peter Bavington characterises it as a

[108] Eric Bianchi believes that the *Harmonicorum libri* probably reached a larger audience than the *Harmonie universelle*, as it was the Latin edition that was republished in the year of Mersenne's death, and not the French one (2015: 168). His supposition is borne out by evidence from the CERL's HPB database: there remain nineteen copies of the *Harmonie universelle* in European and North American libraries and more than sixty copies of the *Harmonicorum libri*. Approximately equal proportions of each work (just over a third) are held by French libraries, particularly the *Bibliothèque nationale de* France (BnF), and most of the rest by other European libraries. The HPB's limited provenance information shows that three copies of the *Harmonie universelle* were previously owned by French individuals and institutions, including Mersenne's own copy, and one each owned by English, German and Italian scholars and libraries, including the Biblioteca Barberini in Rome. The provenance information for the *Harmonicorum libri* shows a higher level of foreign ownership: six British owners, including Edward Herbert, 1st Baron of Cherbury (1583–1648), whose *De veritate* (1624) Mersenne translated in 1639 (Lagrée 1994: 25), three elsewhere in Europe, and only two in France.

‘truncated’ version, with ‘smaller type’ (2012: 15, note 7). All of these descriptions imply that the *Harmonicorum libri* is shorter than the *Harmonie universelle*, but do not suggest that it is a translation of the French work.

Comparison between the *Harmonie universelle* and *Harmonicorum libri* is complicated by the fact that ‘scarcely any two of the extant copies [of the *Harmonie universelle*] have the same contents in the same order’ (Crombie 1981: 321, note 40), a state of affairs that Sir John Hawkins noted in his five-volume *General History of the Science and Practice of Music* (1776, IV: 106). The differences between copies were caused by two principal factors, according to Lenoble and Crombie: Mersenne’s need, described above, to publish individual books separately to raise funds for printing the full works and his decision to make additions and revisions to early reissues (Lenoble 1943: xxii; Crombie 1981: 321, note 40).[109] There are, as noted above, three different title pages, one created by each of the bookseller-printers, and the order of the treatises differs from copy to copy. There is an additional reason hinted at by Mersenne in the *Preface, et advertissement au lecteur* at the beginning of the *Traitez des consonances, des dissonances, et de la composition*: he states that the finished version of the *Harmonie universelle* does not reflect the order in which it was printed and suggests that readers who prefer to read about harmony rather than the physics found in the *Traitez de la nature des sons, et des mouvements* that opens the *Harmonie universelle* might like to begin with the *Traitez des consonances, des dissonances, et de la composition*, as it was printed first (1965d: viii). In fact, Mersenne suggests more generally that the reader should ‘mettre tel ordre que l’on voudra entre ces livres’ [put the books in any order desired] (1965d: viii). This reflects both the printing history of the *Harmonie universelle* and the practice of selling books unbound, which gave readers the freedom to customise their own copies (Martin 1969: I, 388; Benton 2007: 500–01). Mersenne’s remark implies that he saw the treatises less as fixed components of the larger work than as interchangeable, standalone sections of text, originally composed as separate books on a range of musical topics. The order of books in the *Harmonicorum libri* is more straightforward

[109] As Lenoble notes, Mersenne continued to improve the *Harmonie universelle* for the rest of his life, annotating the copy held by the Bibliothèque des Arts et Métiers and published in facsimile edition by the *Centre national de la recherche scientifique* [French National Centre for Scientific Research] (CNRS). The CNRS version is the reference version for this chapter. Its structure is set out in appendix 5, section A (figure 22), followed by discussion of two other versions: Guillo’s notional ‘perfect’ version and the copy available on *Gallica*, the website of the *Bibliothèque nationale de France*.

than in the *Harmonie universelle* in the edition I will be using to compare the two texts.[110] Apart from a few differences with the paratext, this is the same order provided by Guillo's account of the original editions of the volumes (2003: II, 291–93).

In terms of self-translation, of course, the order of the books and treatises in the *Harmonie universelle* and *Harmonicorum libri* matters less than the relationship between them. Comparison of the *Harmonie universelle* and *Harmonicorum libri* reveals that, while they are similar in a number of ways, there are fundamental structural differences between them. Figures 22 and 23 in appendix 5 show, for example, that there is a significant disparity in the number of books they contain, the number of pages in each book, and the volume of paratext. The direct comparison in figure 8 below reinforces the contrast between the number of books in each work, and also demonstrates dissimilarities in both the order in which the books are presented within each work and in the number of pages and the number of propositions they contain.[111]

The most significant difference between the *Harmonie universelle* and *Harmonicorum libri* evident in figure 8 is the number of books: nineteen books in the *Harmonie universelle* and only twelve in the *Harmonicorum libri*. The discrepancy can be explained by two factors. First, there is no equivalent in the *Harmonicorum libri* for three of the books in the *Harmonie universelle:* the *Livre premier de la voix*, the *Livre sixiesme de l'art de bien chanter* or the *Livre de l'utilité de l'harmonie*.[112] Second, the two books on musical composition in the *Harmonie universelle* are matched by the single *Liber octavus de compositione musica* in the Latin work. Similarly, the equivalent of the first four books in the *Traité des instrumens* is the single *Liber primus de singulis instrumentis*. Another major structural difference between the *Harmonie universelle* and *Harmonicorum libri* lies in the order in which the individual books are presented in the two works: although the order of books in the *Harmonicorum libri*

[110] I will be using the version found on the *Gallica* website and described in appendix 5, section B.
[111] As the French version of the work contains the greater number of books, I have used it as the version against which to compare the Latin version in figure 8, and have therefore placed it on the left of the table.
[112] The absence of a Latin version of the *Livre premier de la voix* from the *Harmonicorum libri* led Mersenne's correspondent Aimé de Gaignières *(fl.* 1636–1661) to ask him whether he intended to have one printed (De Gaignières 1960: 193).

HARMONIE UNIVERSELLE					HARMONICORUM LIBRI VIII			
BOOK	**TITLE**	**PAGES**	**PROPS**		**BOOK**	**TITLE**	**PAGES**	**PROPS**
TRAITEZ DE LA NATURE DES SONS, ET DES MOUVEMENTS DE TOUTES SORTES DE CORPS								
Livre premier	'De la nature et des proprietez du son'	84	34		Liber primus	'De natura, et proprietatibus sonorum'	8.5	25
Livre second	'Des mouvements de toutes sortes de corps'	72	22		Præfatio ad eundem		8	4
					Liber secundus	'De causis sonorum, seu de corporibus sonum producentibus'	25.5	43
Livre troisiesme	'Du mouvement, de la tension, de la force, de la pesanteur, et des autres proprietez des chordes harmoniques, et des autres corps'	72	24		Liber tertius	'De fidibus, nervis et chordis, atque metallis, ex quibus fieri solent'	15	22
TRAITEZ DE LA VOIX ET DES CHANTS								
Livre premier	'De la voix, des parties qui servent à la former, de sa definition, de ses proprietez, et de l'oüye'	88	53					
Livre second	'Des chants'	92	27		Liber septimus	'De cantibus, seu cantilenis, earumq; numero, partibus, et speciebus'	50	19
TRAITEZ DES CONSONANCES, DES DISSONANCES, DES GENRES, DES MODES, ET DE LA COMPOSITION								
Livre premier	'Des consonances'	112	40		Liber quartus	'De sonis consonis, seu consonantiis'	18	29
Livre second	'Des dissonances'	28	14		Liber quintus	'De musicæ dissonantiis, de rationibus, et proportionibus'	21	40
Livre troisiesme	'Des genres, des especes, des systemes, et des modes de la musique'	58	20		Liber sextus	'De speciebus consonantiarum, deque modis, et generibus'	26	26
Livre quatriesme	'De la composition de musique'	76	28#		Liber octavus	'De compositione musica, de canendi methodo, et de voce'	24	17
Livre cinquiesme	'De la composition de musique'	52	12					
Livre sixiesme	'De l'art de bien chanter'	109	34					

HARMONIE UNIVERSELLE					HARMONICORUM INSTRUMENTORUM LIBRI IV			
BOOK	**TITLE**	**PAGES**	**PROPS**		**BOOK**	**TITLE**	**PAGES**	**PROPS**
TRAITÉ DES INSTRUMENTS A CHORDES								
Livre premier	'Des instrumens a chordes'	52	20		Liber primus	'De singulis instrumentis ΕΝΤΑΤΟΙΣ, seu ΕΓΧΟΡΔΟΙΣ, hoc est nervaceis, et fidicularibus'	76	44
Livre second	'Des instrumens a chordes'	72	17#					
Livre troisiesme	'Des instrumens a chordes'	76	27					
Livre quatriesme	'Des instrumens a chordes'	52	18#					
Livre cinquiesme	'Des instrumens a vent'	86	35		Liber secundus	'De instrumentis pneumaticis'	40	23#[113]
Livre sixiesme	'Des orgues'	110	45		Liber tertius	'De organis, campanis, tympanis, ac cæteris instrumentis'	32	30
Livre septiesme	'Des instrumens de percussion'	86	31		Liber quartus	'De campanis, et aliis instrumentis, seu percussionis, ut tympanis, cymbalis etc'	24	20
Livre	'De l'utilité de l'harmonie, et des autres parties des mathematiques'	68	18					

Figure 8: Comparative structures of the books in the Harmonie universelle *and* Harmonicorum libri

[113] Four of the books in the two volumes (marked with a #) contain errors in the numbering of their propositions, three in the *Harmonie universelle* and one in the *Harmonicorum libri*. The *Livre quatriesme de la composition* has twenty-eight propositions but, because there are two propositions labelled proposition XXII, all propositions from the second proposition XXII onwards are labelled one number lower than they should be, and the book finishes with proposition XXVII. Similarly, the *Livre second des instrumens a chordes* contains two propositions named proposition XIV and so finishes with propositions labelled XIV–XVI instead of XV–XVII. The *Livre quatriesme des instrumens a chordes* misses propositions V, VI and VII but then repeats proposition VIII, so that both V and VI are labelled VIII, and all propositions from then on are labelled IX–XX instead of VII–XVIII, i.e. they are given proposition numbers two higher than expected. In the *Harmonicorum libri*, the *Liber secundus de instrumentis pneumaticus* has two propositions labelled XV and two labelled XXI; consequently, the propositions from the second proposition XV to the first proposition XXI are labelled one number lower than they should be and the second proposition XXI should be named proposition XXIII.

It is also clear from figure 8 that the French collection of treatises is longer than the Latin version: in total there are 1448 pages in the books in the *Harmonie universelle*, almost four times as many as the 368 pages in the books in the *Harmonicorum libri*.[114]

It should be noted, however, that, despite initial appearances, the *Harmonie universelle* is actually only approximately twice as long as the *Harmonicorum libri*.[115] It should also be noted that the relationships between different pairs of equivalent books are not always the same. For example, at one extreme, once the greater amount of text per page in the *Harmonicorum libri* is taken into account, the *Livre premier de la nature et des proprietez du son*, at 84 pages, is nearly six times as long as the *Liber primus de natura, et proprietatibus sonorum*, which has fewer than nine pages of text, while, at the other, the *Livre second des dissonances* in the French volume is shorter than the equivalent *Liber quintus de musicæ dissonantiis* in the Latin text.

The difference in length between the versions is also reflected in the marked variation in the number of propositions contained within them. In total, there are 519 propositions in the *Harmonie universelle* and only 342 in the *Harmonicorum libri*. This means that there are approximately half as many propositions again in the French text as in the Latin text. As the French text is more than twice as long as the Latin text, this also means that the average French proposition is longer than the average proposition in the Latin work. It should also be noted that, as with the number of pages above, there is a significant difference in the relationship between the numbers of propositions in equivalent books. For example, while the *Livre quatriesme* and the *Livre cinquiesme de la composition de musique* together contain more than twice as many propositions as the equivalent *Liber octavus de compositione musica*, two of the longer French books contain fewer propositions than their shorter Latin equivalents. In addition, the *Livre second des dissonances*, which is slightly

[114] Both figures relate to the total number of pages in the parts of the works on music containing propositions. For the *Harmonie universelle*, this includes the nineteen books with numbered pages, but excludes all of the paratext and the two additional treatises. In the *Harmonicorum libri*, this includes the twelve books with numbered pages and the eight pages of the 'Præfatio ad eundem', which contains four propositions, but excludes the rest of the paratext. The same criteria were also used to calculate the number of propositions in each version of the work.
[115] The *Harmonicorum libri* was printed using a smaller font than the *Harmonie universelle*. Consequently, it contains approximately a third more lines of text per page and approximately a third more characters per line. This means that each page in the *Harmonicorum libri* contains approximately 75% more text per page than each page in the *Harmonie universelle*.

shorter than the equivalent *Liber quintus de musicæ dissonantiis*, has approximately a third of the number of propositions as the Latin text.

The differences between the two versions are not restricted to the treatises and books themselves, but are also true of all aspects of the paratext, from the total number of pages to the title pages, dedications, prefaces, and notices. In terms of length, for example, the *Harmonie universelle* contains 95 pages of paratext compared to 16 in the *Harmonicorum libri*; even taking the discrepancy in font size into account, the paratext is more than three times as long in the *Harmonie universelle* as in the *Harmonicorum libri*. As well as significant differences in text length, there are major disparities within the various types of paratext.[116]

It is clear from the comparison between the finished versions of the *Harmonie universelle* and *Harmonicorum libri* that, as well as being written for different audiences, the two works have significant structural differences in terms of their overall lengths, the number of books contained in them, the order in which the books are presented, the lengths of the individual books as represented by the number of pages and propositions they contain, and their paratexts. As an overall summary, it is true to say, as Mersenne does, that the *Harmonie universelle* is 'bien plus ample' than the *Harmonicorum libri*, as it is twice as long and contains books that are not in the Latin version. However, closer examination reveals that some of the individual books in the Latin version are longer than their counterparts in the French version, or contain more propositions. The lack of direct correspondence between the structures of the *Harmonie universelle* and *Harmonicorum libri* and the greater length of parts of the *Harmonicorum libri* suggest that the Latin version cannot simply be

[116] Both works contain initial title pages with the names of the works, the author and the publisher. The *Harmonie universelle* also contains simple title pages announcing the beginning of each separate treatise in block capitals. The *Harmonicorum libri* has no separate title pages for its eight books, although the *Harmonicorum instrumentorum libri IV* does have its own separate title page. Each of the four treatises in the *Harmonie universelle* has a separate dedication, while the *Traité des instrumens* has a second dedication that follows the first five books and serves as a separate dedication to the *Livre sixiesme des orgues*. In contrast, the *Harmonicorum libri* has just two dedications. Peiresc is the dedicatee of one treatise in each version, but not of corresponding treatises, and the other three treatises in the two versions are dedicated to different men. The two works also contain different numbers of prefaces: there are six in the *Harmonie universelle*, including one general preface, one at the beginning of each treatise and one before the *Livre sixiesme des orgues*, while the *Harmonicorum libri* and the *Harmonicorum instrumentorum libri* have one general preface each. The text of the prefaces is not the same in the Latin and French works. In addition to the dedications and prefaces, the *Harmonie universelle* contains an index for which there is no equivalent in the *Harmonicorum libri*. Both versions contain tables of the propositions, but they are not presented in the same way: while the *Harmonie universelle* contains a single table of propositions for all nineteen books following the general preface at the beginning of the work, the lists of propositions in the *Harmonicorum libri* are placed at the beginning of the books to which they relate.

described either as a 'condensé' or truncated version of the French version or as a translation of it. Instead, comparison of the versions implies that, as was concluded from the creation process, the *Harmonie universelle* and *Harmonicorum libri* are dual works on the same subject, with a large degree of overlap in content, written for different audiences, but each able to stand on its own as one of a pair of original complementary bilingual texts. The next section will explore the relationship between the works at the level of a representative pair of parallel books.

4.3 The *Livre second des chants* and *Liber septimus de cantibus*

The purpose of this section is to compare in detail the *Livre second des chants* and the *Liber septimus de cantibus*, which deal with the same subject, 'songs', in order to shed light on Mersenne's writing practice and investigate the similarities and differences between equivalent books.[117] This will enable me to determine whether either book can be considered the original version or whether they can be considered as dual original books on the subject of 'songs'.

Although they deal with the same subject, there are a number of differences between the structures of the *Livre des chants* and *Liber de cantibus*. The most obvious is that the *Livre des chants* covers ninety-two pages, whereas the *Liber de cantibus* takes up only forty-nine.[118] This would suggest that the *Livre des chants* is significantly longer than the *Liber de cantibus.* However, when the smaller font size and greater number of lines per page in the *Harmonicorum libri* are taken into account, the contrast in length of the books is less significant, though the French book is still longer.[119] More importantly, the number and order of the propositions in the two books is not the

[117] Mersenne's concept of a 'song' in the two books is defined as follows by Coumet: '[p]our Mersenne, un « chant » est une suite de notes' [Mersenne considers a 'song' to be a succession of notes] (1972: 5, note 4). I will use Coumet's definition of the word 'song' for the rest of this chapter.

[118] The *Livre des chants* runs from page 89 to page 180 in the two-book *Traitez de la voix, et des chants*. All but four pages in the book are numbered correctly. The four incorrectly numbered pages are pages 119, 120, 125, and 126, which are numbered as pages 127, 128, 133, and 134 respectively, even though there are also correctly numbered versions of these pages. The errors do not affect subsequent pagination. Where I reference the incorrectly numbered pages, I will number them using their intended page numbers, with an asterisk to show the error, to avoid potentially ambiguous references. The pages in the *Liber de cantibus* are numbered from 113 to 136, then from 133 to 152. Following page 152, six pages of music, numbered pages 52–57, are inserted, and form the end of the chapter. Where needed, references to the second set of pages 133–136 will be marked with asterisks to show that they are the second of the two sets of pages bearing these numbers. All other pages will be referenced using their unique page numbers.

[119] Once the additional number of characters per page calculated in section 4.2.2 above is taken into account, the *Livre des chants* is approximately 10% longer than the *Liber de cantibus*.

same. There are, for example, twenty-seven propositions in the French text and only nineteen in the Latin text.

Figure 9 shows the approximate correspondence between the propositions in the two books.[120] It confirms that the books cover similar material, though in a different order. When the structures are compared more closely, it becomes apparent that sections of the two books correspond with each other. In fact, the two books have approximately the same overall structure: they both begin by defining the terminology and classification of melodies and songs, and both finish with discussions of the same two topics. These parts take up just under a third of each book: ten of the twenty-seven propositions in the *Livre des chants* and six of the nineteen in the *Liber de cantibus*. The majority of the propositions in both books make up the middle section and deal with discussion of whether it is possible to determine rules for finding the best possible songs and how combinatorics can be used to find the total number of songs that can be created from a given number of notes, thereby enabling the ideal song to be identified. This middle section will be the main focus of this comparison of the *Livre des chants* and *Liber de cantibus*.

French	I	II	III	IV	V	VI	VII	VIII	IX
Latin	II		I					III	VI, VII
French	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII
Latin	XIII	IX, X, XI	XIV				X, XII	XIII	
French	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII
Latin	XV		IV		XIX				

Figure 9: Correspondence between the propositions in the Livre des chants *and* Liber de cantibus

The mathematics of combinatorics as it relates to finding the optimum tune or song is covered by propositions VIII to XXI of the *Livre des chants* and propositions III to XV of the *Liber de cantibus*. It should, however, be noted that, although almost the same number of propositions is devoted to combinatorics in the two books, the material is not covered in the same order or in exactly the same way in the two books. For example, there are no equivalent propositions in the *Livre des chants* for propositions V and VIII in the *Liber de cantibus*, and

[120] A fuller version of this table can be found as figure 24 in appendix 5, section C.

no equivalent propositions in the *Liber de cantibus* for propositions XIV, XV, XVIII and XX in the *Livre des chants*, while proposition XI in the *Livre des chants* covers approximately the same material as propositions IX, X and XI in the *Liber de cantibus*. This middle section of both books takes up slightly more space in the *Livre des chants* than in the *Liber de cantibus*: 51 pages in the former compared to 28 in the latter. Given the earlier discussion regarding the relative amount of information per page in each version, this represents approximately 10% more material in the French version than in the Latin version, in line with the overall relationship between the content in the two books.[121]

The only conclusion to be drawn with regard to the relative structures of the *Livre des chants* and *Liber de cantibus* is that the books are clearly twin versions of Mersenne's book on 'songs', but neither can be considered the sole original version, as with the *Harmonie universelle* and *Harmonicorum libri* as a whole. At the simplest level, if either book were a faithful translation of the other, it would be reasonable to expect the books to contain the same number of propositions (and corollaries) in the same order, and to contain the same material in the same order. This brief survey of their structures demonstrates, however, that this kind of correspondence is not a feature of the relationship between the books. Nevertheless, examination of their general overall structures does reveal that the books cover approximately the same material in a similar order, though with some material covered in only one or other of the books. This suggests that the books can be considered as closely related, particularly with regard to the mathematics covered in the largest section in each book: combinatorics.

121 The lack of exact correspondence between the *Livre des chants* and *Liber de cantibus* can also be seen in Mersenne's use of corollaries. There are twenty-three in total in the *Livre des chants* and only eleven in the *Liber de cantibus*, and they are rarely found in corresponding propositions. So, for example, there is one each in propositions VI, VII, X, XII, XVII and XIX, two in propositions VIII, XVI and XX, four in proposition XI, and seven in proposition XXI of the *Livre des chants*, and one each in propositions II, XIV and XV, two in proposition XII, and six in proposition XVIII of the *Liber de cantibus*. Figure 9 shows that only three of the five propositions containing corollaries in the *Liber de cantibus* correspond to propositions with corollaries in the *Livre des chants*, while the remaining two propositions do not have matching propositions in the French book. Similarly, eight of the propositions containing corollaries in the *Livre des chants* either have no corresponding propositions or no corollaries in the corresponding propositions in the *Liber de cantibus*. Even where there is correspondence between the number of corollaries in matching propositions, as with the two corollaries in both proposition XVI of the *Livre des chants* and proposition XII of the *Liber de cantibus*, the correspondence is more apparent than actual. For example, the main purpose of proposition XII of the *Liber de cantibus* is the use of the Arithmetical Triangle to solve a problem involving combinations; this is relegated to the second corollary in the matching proposition in the *Livre des chants,* where it is used as one example of a more general mathematical point.

4.3.1 Combinatorics in the *Livre des chants* and *Liber de cantibus*

In the *Livre des chants* and *Liber de cantibus*, Mersenne's treatment of music as a science, announced in the *Les Préludes de l'harmonie universelle* and evident throughout his musical works, takes the form of an attempt to use combinatorics to find the best possible melody (Cohen 1984: 112), characterised by Lenoble as 'une algèbre des sons' [an algebra of sounds] (1943: 525). This use of combinatorics to find the most beautiful melody can be seen, according to a number of scholars, as part of Mersenne's attempt to rationalise music, using scientific principles to exert a degree of control over music, its composition and its impact (Crombie 1986: 64–65; Dear 1988: 139: Beaulieu 1989: 192; Knobloch 2002: 27). This, according to Patrice Bailhache, places Mersenne in a tradition of 'mathematising' music that both pre-dated and followed him, most clearly seen in the musical writings of Leibniz and Jean le Rond d'Alembert (1717–1783) and based on 'cette idée qu'il suffirait de faire de bonnes mathématiques pour produire de la musique' [this idea that all that would be needed to produce music would be to perform sound mathematics] (1994: 21).

Mersenne dealt with combinatorics in six works altogether, principally in the *Quæstiones in Genesim*, *La Vérité des sciences*, the *Harmonie universelle* and the *Harmonicorum libri* (Knobloch 2002: 28).[122] Very little of Mersenne's theoretical work on combinatorics was original: it is clear that, like Hérigone, he took his theorems from Clavius's *In sphæram Joannis de Sacro Bosco commentarius*. In the *Quæstiones in Genesim*, Mersenne outlines Clavius's second and third problems, while in chapter IX of book III of *La Vérité des sciences*, he gives an account of all three of the problems his predecessor tackled, without mentioning his source in either case. In addition to Clavius, Léon Brunschvicg et al show that permutations and combinations can also be found in the works of a number of other sixteenth-century mathematicians, including English mathematician William Buckley (1519–1592) and Italian mathematicians Pacioli, Tartaglia, and Cardano (1908: 442).[123] One of Mersenne's contemporaries, Jean Beaugrand (*c.* 1595–1640), mentions the

[122] The other works were the *Cogitata physico-mathematica* and the *Novarum observationum*, which were published in the 1640s, after the *Harmonie universelle* and *Harmonicorum libri*.
[123] As well as Mersenne (and Hérigone), Clavius's brief digression on combinatorics influenced a whole host of other seventeenth-century mathematicians, including Leibniz. Clavius himself seems to have taken account of earlier work on the subject, including that produced by Cardano (Knobloch 2013: 131).

general rule for permutations with repetitions in a letter to Mersenne in 1632 (1946: 254). Furthermore, as noted in chapter 3, Hérigone dealt with combinatorics in the Practical Arithmetic book in volume 2 of the *Cursus mathematicus* and *Cours mathématique*, published in 1634, just as Mersenne was completing the *Harmonie universelle* and *Harmonicorum libri*. Mersenne was aware of Hérigone's work, as he recommended it in a letter to Haak in 1639, but does not seem to have used any of the material from the relevant chapter in the Practical Arithmetic. In fact, Mersenne does not acknowledge any of the sources mentioned above. The only source he does mention is Jean Matan, a little-known author of a booklet that forms the basis of proposition V of the *Liber de cantibus* but which does not appear in the *Livre des chants*.[124]

While the mathematics underpinning combinatorics set out in *La Vérité des sciences* is not new, the same cannot be said of the use Mersenne makes of Clavius's work to tackle the question of finding the optimum song, which he characterises in the following manner: '[c]ette difficulté semble estre la plus grande de toutes celles qui sont dans la Musique' [this difficulty seems to be the greatest of all those to be found in Music] (1625: 544). Mersenne pre-empts objections to his search based on the impossibility of the task and the difficulty of listening to and comparing a potentially large number of songs by stating that perfection is attainable in God (1625: 558). To support this task, Mersenne provides a list of the 120 songs made from the five notes of the '*quinte: sol, fa, mi, re, ut'* (1625: 545–47), and a table containing the values of the first fifty factorials for permutations of up to fifty objects (1625: 549–51), both of which also figure later in similar format in the *Livre des chants* and *Liber de cantibus*, where he deals with the same problem again.

In the *Livre des chants*, Mersenne compares the pursuit of the ideal song to establishing rules in medicine, architecture and geometry: if enough scholars put in enough effort to understand music, 'on pourra esperer des regles certaines pour faire de bons chants' [it will be possible to hope for definite rules to make good songs] (1965c: 98). Since the publication of *La Vérité des sciences*, numerous scholars had raised objections to Mersenne's pursuit of the perfect song. He deals with each of these objections in proposition VII of the

---

[124] Mersenne only refers to Matan by his initials in the *Liber de cantibus*, as I.M.D.M.I (1636a: 118). His identity was revealed by Mersenne a number of years later in the *Novarum observationum physico-mathematicorum* (1647: 168).

Livre des chants before introducing the tools he needs to realise his aim: the theorems related to combinatorics, this time without using Clavius's examples. The extent of Mersenne's desire to find the perfect song and thereby demonstrate the efficacy of combinatoric methods can be seen throughout the *Livre des chants* and *Liber de cantibus*. Two examples, both extensions of ideas first seen in *La Vérité des sciences,* stand out. First, he calculates all of the factorials up to 64! by hand (1965c: 108–10; 1636a: 116–17). This is a considerable feat, given that the final factorial contains ninety digits, leading Knobloch to comment: 'To my knowledge, no other author ever calculated — without a computer, of course — a greater factorial' (2002: 31).[125] Second, he writes out all 720 arrangements of six notes, first using the names of the notes, and then as songs using musical notation, applying mathematics to music with what Bailhache characterises as 'un acharnement plus que déconcertant' [a more than unsettling relentlessness] (1994: 21). These two examples take up four and twelve pages respectively in the *Livre des chants*, and three and twelve pages in the *Liber de cantibus* (1965c: 111–15 and 117–28; 1636a: 120–22 and 125–36), a significant proportion of both books. Despite the amount of time and effort Mersenne put into this and longer similar calculations, his work was not always appreciated: Doni annotated the copy of the *Harmonicorum libri* had Mersenne sent him with the comment 'In re tenui labor ingens' [A huge effort for a trivial matter] (Bianchi 2015: 183, including translation).

Although the main purpose behind the use of combinatorics in the *Harmonie universelle* and *Harmonicorum libri* is the optimisation of songs, Mersenne is nevertheless keen to emphasise the application of the rules to other matters, stating in the *Preface au lecteur* to the *Traitez de la voix, et des chants*: 'Le livre des Chants contient encore beaucoup de choses tres-utiles, et tres-remarquables, car les tables des Conbinations [*sic*] peuvent estre appliquées à une infinité de choses' [The *Livre des chants* also contains a lot of very useful and remarkable things, as the tables of Combinations may be applied to an infinite number of things] (1965c: vi). This is something he had also been keen to highlight in *La Vérité des sciences*, referring on that occasion to 'plusieurs autres choses', including the letters of the alphabet (1625: 551). The significance to Mersenne of the use of combinatorics with the alphabet can

[125] It is unfortunate that, because Mersenne's method was recursive, using each answer to calculate the next one, a mistake in calculating 45! means that every factorial after that point is incorrect.

be seen in the second half of the *Preface au lecteur*, where he discusses the creation of a universal writing system (1965c: vii). This was an idea that Mersenne spent a lot of time considering during this period in his intellectual life: in a letter to Peiresc in 1635, he stated that he imagined ‘une sorte d’escripture et un certain idiome universel, qui vous pourrait servir [...] en dressant un alphabet qui contient tous les idiomes possibles, et toutes les dictions qui peuvent servir à exprimer chasque chose en telle langue qu’on vouldra [a kind of universal script and language, which could be useful (…) in drawing up an alphabet that contains all possible languages, and all the words that can be used to express every thing in any language one wants] (1959a: 136). In the *Harmonie universelle*, his proposals can be found in the *Livre premier de la voix*, and so are beyond the scope of this case study.[126]

Mersenne took prior work on combinatorics to develop and support his search for the perfect tune in the *Livre des chants* and the *Liber de cantibus*, a task which he had begun over a decade earlier in *La Vérité des sciences*, on that occasion basing his findings on the work of Clavius. Despite the lack of novelty in the theorems themselves, A. W. F. Edwards believes that the *Harmonie universelle* and *Harmonicorum libri* ‘contain the first accounts of the mathematical theory of permutations and combinations in recognisably modern form’ (2003: 41). Although Edwards does not explain his comment, the *Harmonie universelle* and *Harmonicorum libri* are the first works on combinatorics where an attempt is made to gather data systematically, in tables, so that patterns could be discerned. Importantly for this thesis, the two books on songs contain approximately the same material on combinatorics, both in the works’ many tables and the text accompanying them, including demonstrations and generalisations of results.

4.3.2 Demonstrations and generalisations

Mersenne’s principal approach to demonstrations in both books is to provide lengthy explanations, expressed entirely verbally, without the use of symbols of any kind, either algebraic or arithmetic. One feature of his demonstrations is the choice of different examples to illustrate the same mathematical point in the two books. Another is the tendency to provide a

[126] Further information on Mersenne’s involvement with universal language schemes can be found in Knowlson (1975) and Mary Slaughter (1982).

general rule alongside the example in the Latin text, but not in the French text. As there are far too many examples in the two texts to illustrate every aspect of Mersenne's practice, including many that appear in one of the texts but not the other, in order to demonstrate his approach to straightforward mathematical demonstrations, I will restrict myself to a pair of examples that shows the difference in presentation of the same idea between the two books.

Early in the explanation of the use of permutations and combinations in both books, Mersenne introduces the concept of calculating the number of permutations of a given number of notes. In the *Livre des chants*, the method is explained in the following way:

> Or il est si aisé de trouver le nombre de ces chants, […] car il faut seulement escrire autant de nombres selon leur ordre naturel, comme il y a de notes dont on veut user; par exemple, si l'on veut sçavoir combien l'on peut faire de chants differents avec les huict sons, ou les 8 notes de l'Octave, *ut*, *re*, *mi*, *fa, sol*, *re*, *mi*, *fa*, il faut escrire 1, 2, 3, 4, 5, 6, 7, 8, et multiplier tellement ces 8 nombres, que le produit des deux soit toujours multiplié par le nombre naturel en cette manière; une fois deux font deux; car il faut laisser l'unité, parce qu'elle ne multiplie nullement, et dire deux fois trois font six, quatre fois six font vingt-quatre, cinq fois 24 font 120, six fois 120 font 720, à sçavoir le nombre de tous les chants des six notes […]: sept fois 720 font 5040, et huit fois 5040 font 40320, qui monstre le nombre des chants qui sont contenus dans 8 sons differens
>
> [Now it is so easy to find the number of these songs, (...) as all that is required is to write down as many numbers as there are notes that one wants to use in their natural order; for example, if one wants to know how many different songs can be made with eight sounds, or the eight notes in the Octave, *ut*, *re*, *mi*, *fa, sol*, *re*, *mi*, *fa*, one needs to write down 1, 2, 3, 4, 5, 6, 7, 8 and multiply these 8 numbers in such a way that the product of the pair is always multiplied by the natural number in this way: once two makes two, as unity must be left because it does not multiply at all, and say twice three makes six, four times six makes twenty-four, five times 24 makes 120, six times 120 makes 720, namely the number of all the songs with the six notes [...]; seven times 720 makes 5040, and eight times 5040 makes 40320, which gives the number of songs that are contained in eight different sounds] (1965c: 107).

In this instance Mersenne simply provides a lengthy description of the mathematical operations required to find the solution in an individual case. In the *Liber de cantibus*, by contrast, he precedes a much shorter example with a general rule:

[F]acile vero reperitur ista varietas, si totidem ab unitate numeri serie continua, et naturali scribantur, quot notæ vel aliæ res conjungendæ, variandæque proponuntur; illi si quidem seipsos multiplicantes dant numerum varietatum. Exempli causa quatuor Tetrachordi notæ, *Ut, re, mi, fa* proponantur, scribanturque sequentes numeri 1, 2, 3, 4, qui se hac ratione multiplicantes semel bis faciunt 2: bis ter dat 6: quater vero sexies faciunt 24: quapropter hæ quatuor notæ viginti quatuor mutationes patiuntur

[This variety (i.e. number of arrangements) can easily be discovered, if as many natural numbers are written down from unity in an uninterrupted series as notes or other variable things are set out to be joined together; accordingly, when multiplied together, they give a number of varieties. For example, the four notes of the Tetrachord, *Ut, re, mi, fa*, are set out, and the following numbers 1, 2, 3, 4, are written down, which are multiplied together in such a way that once twice makes 2; twice three times gives 6; four times six makes 24: which is why these four notes allow twenty-four changes] (1636a: 116).

In this example from the Latin book, Mersenne adds the instruction to multiply the numbers in the general case, not just in the specific cases of the eight notes of the octave or the four notes of the tetrachord.

In mathematical terms, the main features common to both explanations are, as noted above, their wordiness and the lack of symbols.[127] From a self-translation perspective, the key additional features are the presence of the general rule in the Latin text and its absence from the French text, and the use of different sets of notes and numbers as the basis of the examples to demonstrate the use of the same mathematical technique. The presence of the general rule in the *Liber de cantibus* and the brief example that follows it suggests that Mersenne felt he was dealing with a more learned audience than he was in the *Livre des chants*. The longer example in the *Livre des chants* allows Mersenne to show more calculations to ensure that a potentially less mathematically sophisticated audience understands the concept in question.

As with demonstrations, Mersenne does not use the same examples in the *Livre des chants* and *Liber de cantibus* to generalise the application of combinatorics to subjects other than songs. And, as with demonstrations, the text is distinctly different, even when similar examples are used, as the following

[127] In modern mathematics, for example, the number of arrangements of notes would be stated in the first example as $8! = 1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 \times 8 = 40{,}320$, in the second as $4! = 1 \times 2 \times 3 \times 4 = 24$ and in general as $n! = 1 \times 2 \times \ldots . \times (n-1) \times n$.

pair of examples will show. In proposition XI of the *Livre des chants*, Mersenne describes permutations of any number of notes from the twenty-two available in the triple octave, where all repetitions are allowed, in the following way:

> Cette combination est la plus generale de toutes […]; de sorte que cette regle contient tout ce que l'on peut s'imaginer dans toutes les varietez et les combinations des notes, ou de telles autres choses que l'on veut; car tout ce qui se dit des notes peut estre appliqué aux nombres, aux lettres, aux soldats, aux fleurs, aux couleurs, etc.
>
> [This combination is the most general of all (...), in such a way that this rule contains everything imaginable in every variety and combination of notes, or any other things that one might want; for everything that has been said about notes may be applied to numbers, letters, soldiers, flowers, colours, etc] (1965c: 135).

He also generalises the use of permutations and combinations at the end of proposition VII in the *Liber de cantibus*, where he states:

> Sed et hæc combinatio, seu transpositio notarum, atque litterarum aliis rebus in infinitum potest accommodari, verbi causa numeris, floribus, militibus, atomis, qualitatibus, elementis, etc.
>
> [However, this combination, or transposition of notes, and also letters, can be infinitely adapted to other things, for example numbers, flowers, soldiers, atoms, characteristics, elements, etc.] (1636a: 123).

As with demonstrations, the ideas expressed in the two passages are very similar, but are expressed in noticeably different fashions. In both texts, the concept of generality of application is conveyed implicitly by the use of 'etc'. This implicit generalisation is supported in the Latin text by the use of the notion of infinite application ('in infinitum'); explicit generalisation, in the shape of the phrase 'la plus generale', is reserved for the French text, perhaps to emphasise the idea for the French audience. It is notable too that the areas to which this technique may be generalised are wider in the Latin text than in the French text: in addition to numbers, letters, soldiers, and flowers, the technique can be applied to scientific topics such as atoms and elements with which the Latin-reading audience would have been more familiar.

This brief examination of the similarities and differences between Mersenne's mathematical demonstrations and generalisations in the two books has shown that he frequently uses different examples in the books and, when the examples are similar, he does not choose the same numbers, with the result that the calculations and explanations vary in nature according to the language used. This survey has also shown that, when the examples are similar, Mersenne tends to use more text to ensure the French-reading audience understands the mathematics he is explaining. In addition, he provides general rules in the Latin text that do not appear in the French texts. From a self-translation perspective, these differences mean that neither book can be considered the source from which the other has been translated; instead, it implies that the two books should be viewed as twin versions of Mersenne's book on songs, written for different audiences. Comparison of Mersenne's use of tables and his fascination with large numbers in the two books will enable me to explore this relationship further.

4.3.3 Large numbers and tables

Domenico Meli believes that 'Mersenne took an aesthetic and intellectual pleasure both in numbers and in their tabulations', particularly in the *Vérité des sciences* and the *Harmonie universelle* (and, by extension, the *Harmonicorum libri*) (2004: 184). In the *Livre des chants* and *Liber de cantibus*, the pleasure in numbers manifests itself particularly as an interest in *very large* numbers. It is likely that this interest in large numbers had a religious dimension: Alex Bellos suggests that this fascination, which is also manifest in Buddhist writings and ancient Sanskrit literature, 'was metaphysical in nature, a way of groping towards the infinite and of grappling with life's big existential questions' (2020: 116). In practice, finding the number of arrangements of a set of n objects — the first use of combinatorics in each book — involves large numbers for relatively low values of n.[128] Consequently, both books are full of these numbers, and they can mainly be found in the books' many tables. I will begin this section by examining two examples of Mersenne's delight in the use of large numbers that do not involve tables before going on to investigate his frequent use of tables to represent his results with large numbers.

Unlike mathematical demonstrations and generalisations, none of the examples in the two books that deal with large numbers use the same context.

[128] For example, $10! = 3{,}628{,}800$: multiplying the first ten natural numbers gives the number of arrangements of ten objects, which involves seven digits. The magnitude of the numbers grows rapidly: 20! involves nineteen digits and 30! thirty-three digits.

Nevertheless, in common with the previous examples, the purpose behind the examples is clearly similar: to use analogy to provide the reader with a concrete framework within which to comprehend the scale of the numbers involved. The first instance comes from the *Livre des chants*. In this example, Mersenne follows his explanation, which I used as an example above, of how to find the number of possible songs using each of the eight notes in an octave once each by discussion of the same calculation with the twenty-two notes in the triple octave. So large is the resultant number, he says, that:

> il faudroit beaucoup plus de rames de papier pour noter tous les chants qui se trouvent dans 22 notes, encore que l'on n'en repete jamais aucune deux fois, qu'il n'en faudroit les unes sur les autres depuis la terre jusques au firmament, encore que chaque fueille de papier contint 720 chants differens chacun de 22 notes, et que chaque rame de papier fust tellement pressee et battuë qu'elle ne fust pas plus épaisse qu'un pouce, c'est à dire que la 12 partie d'un pied de Roy: car il n'y a que 28862640000000 pouces du centre de la terre aux estoilles: or le nombre des rames de papier qu'il faudroit pour noter lesdits chants est mille fois plus grand que ce nombre de pouces
>
> [many more reams of paper would be needed to note down all of the songs that can be found in 22 notes, even if none of them were repeated twice, than would be needed if they were placed on top of each other from the earth to the firmament, even if each sheet of paper contained 720 different songs each of 22 notes, and each ream of paper were so pressed and beaten down that it were no thicker than an inch, that is to say the twelfth part of the King's foot; for there are only 28,862,640,000,000 inches from the centre of the earth to the stars, yet the number of reams of paper needed to note down said songs is a thousand times greater than this number of inches] (1965c: 108).[129]

This example does not appear at all in the *Liber de cantibus*, but Mersenne does use a similar strategy to convey the magnitude of large powers of two using analogy in two examples in proposition X of the Latin book. In the second example he describes what would happen if a grain of wheat were placed on the first square of a chess board and the number of grains on each

[129] The 'pied du Roy', known as the royal or Paris foot, was slightly longer than a British imperial foot (Rowlett 2013: 285). The 'pouce', like the imperial inch, was a twelfth of a foot, and so was also slightly longer than the imperial equivalent (Rowlett 2013: 295). The calculation is slightly wrong — the number of reams needed would be a hundred, not a thousand, times greater than the distance stated — but this does not significantly lessen the impact of the example.

subsequent square were doubled.[130] He states that the outcome would be a total of 8,964,821,659,670,028,096 grains of wheat, which, he says 'cum ne quidem omnes naves totius mundi sufficiant ad frumentum capiendum, aut ferendum, quod ex illis granis exurgit' [not even all of the ships in all the world would be enough for the wheat that grows from these grains to be taken on board, or carried] (1636a: 134*).[131]

From Mersenne's perspective, the desired impact of these two examples is the same, even if the examples themselves are different: he uses them to appeal to the same sense of wonder and fascination with the infinite in the audience that he feels himself when faced with large numbers. His technique in doing so involves demonstrating to the reader that, very quickly, even with relatively small numbers of objects, we are dealing with large numbers of permutations, the magnitude of which is almost incomprehensible: appreciation of the numbers requires the reader either to visualise a pile of paper reaching a thousand times further than the distance to the stars or more grains of rice than can be carried by all the ships in existence. The same effect has been obtained, although in different contexts in the two books, so that, from a self-translation perspective, neither example can be said to have been translated from the book in which it appears to the other. Instead, the two examples exist as original examples within their own books. Mersenne's use of very large numbers again emphasises the relationship between the two books as complementary discussions of the same topic.

The two examples above involve explanations provided by Mersenne in the main text of the books. The principal location for large numbers in the *Livre des chants* and *Liber de cantibus* is, as Meli suggests, not the text itself, but

[130] This is a well-known example used to show how quickly geometric progressions (and exponential functions) increase. It appears to have been first discussed in writing in the thirteenth century by the Islamic scholar Ibn Khallikan (1211–82). He relates the legend of mythical Grand Vizier Sissa ben Dahir who was said to have been asked by Indian King Shirham to name his reward for inventing the game of chess. The king was unaware of the enormous amount of wheat this would entail (Pickover 2009: 102). It is interesting to note that the total number of grains in the first n squares has the general form $2^n - 1$; these numbers are known as Mersenne numbers because Mersenne used the formula as a test to check for prime numbers. In fact, there are nine Mersenne primes on the chess board (Danesi 2018: 51–52)

[131] Unfortunately, Mersenne's calculation, which appears to relate to the number of grains on the 64th square, and not the total number of grains on the chess board, is slightly wrong (by less than 3%). With the benefit of a modern calculator, it is possible to calculate the intended number of grains of wheat as $2^{63} = 9{,}223{,}372{,}036{,}854{,}775{,}808$. The total number of grains on the board is equal to $2^{64} - 1$. Mersenne's fascination in very large numbers can also be seen in his correspondence: in the letter to Peiresc about universal languages in 1635, he describes an alphabet with 'plus de millions de vocables qu'il n'y a de grains de sable dans toute la terre' [more millions of terms than there are grains of sand in the entire world] (1959a: 136).

Mersenne's many tables (2004: 184). The enthusiasm for numbers can be felt most keenly in the tables of permutations from 23 to 64 in both books: the 'Table de la Combination depuis 23 jusques à 64' (1965c: 109–10) and the 'Tabula Combinationis à 23 usque ad 64' (1636a: 116–17). Mersenne takes great delight in announcing that the final number in the tables has ninety digits, and then takes a paragraph in the *Liber de cantibus*, but not the *Livre des chants*, to write it out in full in words, beginning with '[d]ucenti viginti et unus vigintioctoiliones' [Two hundred and twenty-one octovigintillions] (1636a: 116).[132] In his eighteenth-century history of music, Hawkins quotes Mersenne's full number and identifies the same impact on the reader as noted in the examples above: 'in these [tables] the varieties appear so multifarious, that the human mind can scarce contemplate' (1776: IV, 108).

Coumet identifies three reasons why Mersenne uses tables to such a great extent in these two books in particular: to provide results to allow general rules to be established, to convince the sceptics, and because '[l]es tables de toutes sortes tenaient [...] une place privilégiée dans la pratique mathématicienne' [tables of all kinds held (...) a privileged place in mathematical practice] (1972: 11–13). While the second reason provided by Coumet is very specific to Mersenne's mission, the first and third reasons tally with John Mumma and Marco Panza's summary of the use of diagrams in general in mathematics. They observe that '[d]iagrams are ubiquitous in mathematics', serving to 'introduce concepts, increase understanding, and prove results' (2012: 1). Mersenne uses tables in the *Livre des chants* and *Liber de cantibus* primarily for the first two of these purposes — to introduce combinatoric concepts and to increase understanding of them as useful tools for other mathematicians. He states in the *Preface au lecteur* to the *Traitez de la voix, et des chants* that the tables in the French books (and, by extension, those found in the Latin books) will be of great use to mathematicians seeking general applications of the results he has tabulated: 'les tables des Conbinations [*sic*] peuvent estre appliquées à une infinité de choses, et soulageront grandement

[132] An 'octovigintillion' is equivalent to 10^{87} in the short-scale system used for naming powers of 10 in many northern European countries and in South America. In this system, as in Mersenne's 90-digit number, each successive '*n*-illion' describes a sequence of three digits and is equal to $10^{3(n+1)}$. Hence, a trillion is equal to 10^{12}, a quadrillion to 10^{15}, a quintillion to 10^{18}, etc. Modern French (and modern north American and much southern European) usage favours the long-scale system, where each successive '*n*-illion' describes six digits and is equal to 10^{6n}. The long-scale equivalent to an octovigintillion is a thousand 'quattuordecillions' (1000×10^{84}) (Cauty 1998: 465–68).

ceux qui ont des operations à faire' [the tables of Combinations may be applied to an infinite number of things, and will make it easier for anyone who needs to carry out operations] (1965c: vi).

From a self-translation perspective, the main question with regard to tables, as with all of the other textual features discussed above, is the extent of their similarity or difference in the two books and the implications for the potential audiences of the two books. In his description of the extant copies of the *Harmonicorum libri*, Guillo states that '[l]es illustrations sont les mêmes que celles de l'*Harmonie universelle*' [the illustrations are the same as in the *Harmonie universelle*] (2003: II, 291). While this is largely the case for the tables in the *Livre des chants* and *Liber de cantibus*, it is not universally true: some tables appear in only one of the books, and the tables are presented differently in the two books.

There are seventeen tables in the fifty-one pages that cover propositions VIII to XXI of the *Livre des chants*, and eighteen tables in the thirty-two pages containing propositions III to XV of the *Liber de cantibus*, i.e. the propositions dealing with combinatorics. Fifteen of the tables in each book are common to both, showing a very high degree of overlap between them. Typical of the small number of tables that are not common to both books is the 'Table de tous les Chants et de toutes les dictions qui se peuvent faire de 22 notes, ou de 22 lettres' [Table of all the Songs and words that can be made from 22 notes or 22 letters] in proposition XIII of the *Livre des chants* (1965c: 137). Mersenne presents this table to demonstrate his method for determining the position of any given song in the list of all possible songs. As with all of the tables that are not common to both books, the table is linked to content that is not included in the *Liber de cantibus*.

Because the majority of the tables are common to both books, they include almost exactly the same information: most of the tables contain either arrangements of notes (using musical notes or the names of the notes) to demonstrate permutations and combinations, or they contain lists of numerical results. This information is presented in a similar order in the two books. Only three of the fifteen common tables could be said to be provided in a different order: two of these tables differ in other respects as well, which may partly explain the divergence in comparative ordering. For example, one of them, known as the ‘Table des Chants qui se peuvent faire de 9 notes’ [Table of songs that can be made from 9 notes] in the *Livre des chants* and as the ‘Tabella novem notarum singularis’ [Unique table of nine notes] in the *Liber de cantibus*, provides slightly different information in the two books: in the Latin book the table shows the number of different songs that can be made from nine notes selected from the twenty-two in the triple octave, while the table in the French book simply shows the number of songs that can be made from a total of nine notes (1965c: 130; 1636a: 139).

Although the majority of the tables used in the books are common to both of them, there are significant discrepancies between the ways in which they are presented. The first set of differences involves the titles of the tables: the lack of titles for a minority of tables, the use of words meaning ‘table’, and disparities in the terminology used in the titles. Most of the tables have titles, with the exception of two in the *Liber de cantibus* and one in the *Livre des chants*. The lack of a title is especially surprising in two of the three cases, given that the tables are common to both books and are given titles in the other language.[133] Most of the tables that do have titles contain a word meaning ‘table’ in the title: ‘table’ in French, but both ‘tabula’ and, less frequently, its diminutive ‘tabella’ in Latin. There does not seem to be any distinction made between the tables known by the name ‘tabula’ and those called ‘tabella’: one of the bigger tables, the ‘Tabella pulcherrima et utilissima Combinationis duodecim Cantilenarum’ [The most beautiful and most useful table of the Combination of twelve Songs], which shows part of the Arithmetic Triangle, is described using the Latin diminutive form, for example (1636a: 136*).

The other major difference between the titles of the tables in the two books is their level of formality, particularly their use of mathematical terminology. The contrast between the two books is most noticeable in the use of the word ‘combination’: this appears in the titles of eight of the eighteen tables in the *Liber de cantibus*, but in only one of the titles of tables in the *Livre*

[133] One of the tables is known in the French book as the ‘Table des 256 Varietez de quatre temps differens’ [Table of the 256 Varieties from four different time signatures] (1965c: 150–51). It is introduced in the Latin text but has no title (1636a: 142). The same is true in reverse for the other table: its title in the *Liber de cantibus* is ‘Varietas, seu Combinatio quatuor notarum’ [Varieties or Combinations of four notes] (1636a: 117), but it is simply introduced in the text of the *Livre des chants* and no title is provided (1965c: 154).

des chants. So, for example, as shown in figure 10 below, the ‘Tabula Combinationis ab 1 ad 22’ [Combination table from 1 to 22] is known as the ‘Table de tous les chants qui peuvent se rencontrer dans 22 sons, c’est à dire dans trois Octaves’ [Table of all the songs that might be found in 22 sounds, i.e. in three octaves] (1636a: 116; 1965c: 108). The difference in this example is typical of many of the titles of tables in the two books: where the Latin title is formally mathematical and divorced from the musical context, and therefore more general, the French title deals with the more practically applicable question of the number of songs. This is also true in one title with more complex mathematical terminology: the ‘Tabula Methodica Conternationum, Conquaternationum, etc. utilissima’ [Methodical and useful table of Conternations, Conquaternations, etc.] is rendered in French as the ‘Table des Chants de 12 notes, ou des jeux differens du Piquet pris en 36 notes ou chartes’ [Table of the Songs with 12 notes, or of the different hands of Piquet, chosen from 36 notes or cards] (1636a: 137; 1965c: 146). In this example, the practical context of arrangements of musical notes and playing cards is again preferred in the *Livre des chants* to the general mathematical title in the *Liber de cantibus*. The contrast in the choices of titles highlighted in this paragraph can almost certainly be explained by Mersenne’s divergent expectations of his different audiences. The Latin-reading audience is assumed to be expecting tables that display the theoretical mathematics of combinatorics while the expectation of the French-reading audience is that they will be more appreciative of, and comfortable with, the practical applications of the theory.

As well as differences in their titles, the other notable discrepancies between the tables involve the layout of the tables and the use of numerals within them. The majority of the tables that are common to the two books contain additional lines to separate the columns in the *Livre des chants* alone, and some also contain additional explanatory columns. Figure 10 demonstrates a significant variation in the use of numerals: the tables in the Latin book use roman numerals to label the base number for a calculation, while the French tables generally use arabic numerals. As with the differences in the titles of the tables, the contrast in layout and the use of numerals may be attributable to different expectations for Mersenne’s two main audiences. It seems equally likely that it was a consequence both of contemporary printing conventions

Tabula Combinationis ab 1 ad 22.

I	1
II	2
III	6
IV	24
V	120
VI	720
VII	5040
VIII	40320
IX	362880
X	3628800
XI	39916800
XII	479001600
XIII	6227020800
XIV	8717819·100
XV	1307674368000
XVI	20922789888000
XVII	355687428096000
XVIII	6402373705728000
XIX	121645100408832000
XX	2432902008176640000
XXI	51090942171709440000
XXII.	1124000727777607680000

‘Tabula Combinationis ab 1 ad 22’ (1636a: 116)

Table de tous les chants qui peuvent se rencontrer dans 22 sons ; c'est dans trois Octaues.

1	1
2	2
3	6
4	24
5	120
6	720
7	5040
8	40320
9	362880
10	3628800
11	39916800
12	479001600
13	6227020800
14	87782912OO
15	1307674368000
16	20922789888000
17	355687428096000
18	6402373705728000
19	121645100408832000
20	2432902008176640000
21	51090942171709440000
22	1124000727777607680000

‘Table de tous les chants qui peuvent se rencontrer dans 22 sons, c’est à dire dans trois Octaves’ (1965c: 108)

Figure 10: Tables showing differences in titles, mise-en-page and use of numerals in the Livre des chants *and* Liber de cantibus

and of using two printers at slightly different times: either the printers did not have the same conventions for displaying and printing tables, or Mersenne and Cramoisy, the printer of the *Harmonie universelle*, may have decided to improve the appearance of the tables for the later version.

In conclusion, it is clear that Mersenne took great pleasure in numbers, particularly very large numbers, and in sharing his sense of wonder with his audiences. I have shown in this section that he used different examples in the *Livre des chants* and *Liber de cantibus* to create a similar impact on his separate French- and Latin-reading audiences. In addition to these examples, the middle sections of the books are replete with tables showing the large numbers that result from calculations with combinatorics. As well as enjoying tabulating numbers, Mersenne wanted the tables to be of use to researchers both for generalisation and a range of applications. There are discrepancies in the ways in which the tables are presented in the two books and in the complexity of terminology in their titles that show differences in printing conventions and Mersenne's view of his audiences' expectations. Nevertheless, the majority of the tables in the two books represent the same mathematical results in approximately the same order. The large degree of commonality in the tables and the impact of the use of large numbers implies that the two books can be considered as twin versions of Mersenne's book on songs. The additional complexity found in the tables in the Latin book suggest that it cannot be considered a translation of the longer French book, but should be considered as complementary to it.

4.3.4 Mathematical language: terminology and phrases

Mersenne's use of mathematical language in the *Livre des chants* and *Liber de cantibus* can be divided into three types, as with Hérigone: terminology relating to the structure of the books, terminology relating to mathematical concepts, and the phrases of mathematical rhetoric that he uses as a framework for his mathematical demonstrations. In this section, I will examine each of these types of mathematical language in turn, focusing particularly on the terminology of combinatorics.

Both the *Harmonie universelle* and the *Harmonicorum libri* are structured as extended mathematical treatises, with each constituent book split up into a series of propositions. However, in the *Preface au lecteur* at the beginning of the *Traitez de la nature des sons*, *et des mouvements,* Mersenne warns the reader that he has been lax in his use of correct mathematical terminology as it relates to the structure of the books:

> il faut encore remarquer que je n'ay pas tousjours usé de la diction *Corollaire* en sa propre signification, et que je desire qu'on la prenne comme si elle signifioit *Advertissement*, *Proposition*, *Scholie*, etc. selon ce que je traite dedans, afin que ce mot ne choque personne, et que les vocables, aussi bien que les resolutions, se prennent à discretion, et puissent estre accommodez à l'humeur et au contentement des Lecteurs, qui doivent faire plus d'estime de la verité que des beaux mots, et qui ne doivent pas tant prendre garde à la proprieté des paroles, qu'à ce qu'elles contiennent
>
> [it should also be noted that I have not always used the correct meaning of the term *Corollary* and would like it accepted as meaning *Notice*, *Proposition*, *Scholia*, etc., depending on the subject matter, so that no one is shocked by the word and so that the titles and solutions are taken

> with some latitude, and may be adapted to the mood and satisfaction of the Readers, who ought to have a higher regard for the truth than for fine words and who ought not so much pay attention to the appropriateness of words as to what they contain] (1965b: vii).

Mersenne uses the preface in this way in order to pre-empt criticism that his approach in the *Harmonie universelle*, the French version of his work, is not rigorously mathematical. He does so by appealing to a more noble motive — the search for the truth — and by flattering his audience as joint seekers of this truth. Mersenne's appeal is a clear example of rhetorical invention, where he argues for the plausibility of his arguments in favour of excusing his lack of rigour.[134] He would have been aware that, although some of his French-reading readers approached the volume as musicians and not as mathematicians, many others were scholars who expected the level of rigour seen in the mathematical treatises that the layout of the *Harmonie universelle* suggests was Mersenne's aim. The imprecise use of mathematical terminology for which Mersenne expects criticism is exemplified by his description of proposition I in the *Livre des chants* as 'ce premier Theoréme' [this first Theorem] (1965c: 91). The proposition is a very long description in which Mersenne attempts to define the meaning of 'chant' and 'air'. It is neither a mathematical proposition nor a theorem in any strictly mathematical meaning of the terms.

The terminology used in the *Livre des chants* to describe the component parts of the mathematical works, propositions and demonstrations contained within them includes: 'demonstrer' [demonstrate], 'demonstration', 'methode' [method], 'proposition', 'corollaire' [corollary], 'table', 'regle' [rule], 'exemple' [example], and 'termes' [terms]. Equivalent terminology is used in the *Liber de cantibus*: 'demonstratus', 'methodo', 'propositio', 'corollarium', 'exempli', and, as discussed above, 'tabula' and 'tabella'. All of the words used in both books were well-established mathematical terms by the 1630s.[135] Because a number of these terms have standard functions within mathematical texts, they are used in

---

[134] Cicero defined 'invention', the first stage in composing a speech, as 'the discovery of valid or seemingly valid arguments to render one's cause plausible' (quoted in Vickers 1988: 62). This accurately describes Mersenne's attempts at justification in this instance. Traditional Greek rhetoric comprised four elements*:* 'invention', 'disposition', 'elocution', and 'delivery'. Invention involved the assembling of proofs and arguments, disposition, the arranging of this material in the most effective order, elocution, the art of presenting each argument as clearly and persuasively as possible, and therefore in the most appropriate language, while delivery involved the appropriate intonation, gestures and expressions for public delivery (Topliss 1966: 13). By the seventeenth century, significant changes had taken place within rhetoric: delivery was now largely disregarded 'since Rhetoric was now chiefly applied to the written word; the precepts of the other three were closely followed' (Topliss 1966: 13).

[135] As can be seen in appendix 3.

the same way in both books. This is clearly the case with pairs of cognate terms such as ‘proposition’ and ‘propositio’, ‘corollaire’ and ‘corollarium’ and ‘table’ and ‘tabula’ or ‘tabella’: all of these terms have very specific functions as labels for sections of text and images. However, although the terms are clearly intended as direct equivalents in the two languages, the lack of correspondence between the numbers of propositions, corollaries and tables in the two texts, the order in which the propositions and tables occur, and the locations where the tables and corollaries are placed, means that they are used to produce two versions of the same text rather than a faithful translation. The same can be said about the other terms: they describe features of both mathematical texts (demonstrations, terms, methods, rules), but are not used in the same locations in the two texts. This use of the terminology of the mathematical structure of the books again reinforces the notion of separate dual texts.

The mathematical terminology found throughout the main text of both books was also well embedded in mathematical use by the time the books were written.[136] As with the terminology of the mathematical structure of the books described above, the majority of the mathematical terms used are cognates. However, in the same way as that terminology, they are not always used in precisely the same context, and some of the terms used in one or other of the books do not appear in the other book. Two simple examples of the latter include the lack of use of the cognate term for ‘pouce’ in the Latin book and for ‘imparum’ in the French book (1965c: 108; 1636a: 125); ‘pouce’, for example, is used in the first example cited in section 4.3.3 above, an example that does not appear in the *Liber de cantibus*.

[136] In the case of the *Livre des chants*, this included number-related terminology such as ‘nombre’ [number], ‘nombre naturel’ [natural number], ‘somme’ [sum], ‘zero’, ‘unité’ [unity, or one], ‘double’, ‘mille’ [thousand], ‘million’ (from the Italian ‘milione’, meaning ‘a thousand thousands’, according to Rey and Rey-Debove 1983: 1202), ‘chifre’ [digit], ‘infiny’ [infinite], and ‘quantiesme’ [nth (literally the ‘*how many*th’)], terms relating to measurement, including ‘pied de Roy’ [royal foot] and ‘pouce’ [inch], the terminology of mathematical operations, such as ‘multiplier’ [to multiply], ‘diviser’ [to divide], ‘diviseur’ [divisor], ‘division’, ‘ajouter’ [add], ‘addition’, ‘oster’ [subtract and divide], ‘quotient’, and ‘produit’ [product], and terms related to powers, roots and sequences, including ‘doubler’ [to double], ‘quarrer’ [to square], ‘le quarré’ [the square], ‘cube’ [the cube], ‘cuber’ [to cube], ‘quarrer’ [raise to the power of four, i.e. square the square], ‘progression Geometrique’ [geometric progression], and ‘racine’ [root]. Similar terminology can be found in the *Liber de cantibus*: the terminology associated with numbers, such as ‘numerus’ [number], ‘naturalis’ [natural number], ‘imparum’ [odd number], ‘summa’ [sum], ‘unitas’ [unity, or one], ‘dimidius’ [half], and ‘producto (numero)’ [(number) product], the terminology of mathematical operations, such as ‘multiplicare’ and ‘ductare’ [both to multiply], ‘multiplicatio’ [multiplication], ‘dividare’ [to divide], ‘dividendus’ [dividend, or number to be divided], ‘plus’, ‘additio’ [addition], ‘subtractio’ [subtraction], ‘subtrahere’ [to subtract], and terms related to powers, roots and sequences, including ‘quadratum’ [the square], ‘cubus’ [the cube], ‘progressio Geometrica’ [geometric progression], ‘series’, and ‘sequens’ [sequence]. Information on the date of first recorded use of the mathematical terms can be found in appendix 3.

Use of cognate terms is also a feature of the terminology of combinations in the two books. The principal terms Mersenne uses to describe not only combinations but also all of the various types of permutation in the French and Latin books are the cognates 'combination' and 'combinatio', both almost always used in the singular. His use of terms had changed since the *Vérité des sciences*. In that work, his examples were taken from Clavius, as noted in section 4.3.2, and so was his terminology: he generally used 'combination' for 'combination' and 'conjonction' for 'permutation', though for the latter concept he also used 'transposition', like Hérigone in the *Cursus*, 'mutation', and the Greek term 'metathêse' (1625: 534–43). Descotes states that the names for combinations was not yet fixed when Mersenne was writing (2001b: 44), a statement that rings true when his use of vocabulary is examined in detail.[137]

Mersenne's use of the cognate terms 'combinatio' and 'combination' brings with it two potential problems, the first easily resolved by Mersenne, the second less so. Strictly speaking, 'combinatio' (and 'combination') should only apply to two objects. Jakob Bernoulli (1654–1705) noted in the *Ars conjectandi* [The Art of Conjecturing] (written 1684–89, published 1713), his summary of previous work on combinatorics, that some writers used 'combination' in this strict original sense of joining together two objects, or 'binaries', and so used the terms 'conternation', 'conquaternation' and so on when combining three or more objects in 'ternaries', 'quaternaries' and larger groups (1795: 54). Mersenne makes it clear in the *Liber de cantibus*, however, that he will use 'combination' for any number of objects, explaining that: 'Quamvis vocabulum *Combinationis* proprie solummodo dicatur de duabus rebus, quæ conjunguntur, aliis tamen trium, quatuor, et plurium rerum omnifariis varietatibus solet accommodari' [Although the term *Combination* is only specifically used for two things that join together, nevertheless it tends to be adapted to all sorts of other varieties of three, four, and more things] (1636a: 118).

More problematic in the *Livre des chants* and *Liber de cantibus* is Mersenne's use of the single pair of terms 'combinatio' and 'combination' for both permutations and combinations. This leads to a lack of clarity in the books, particularly as Mersenne never actually defines precisely what he intends

[137] By the time Pascal wrote the treatises on the Arithmetic Triangle, the French term 'combination' had been replaced by 'combinaison'. Hauchecorne's suggestion that the new term was first used around 1670 implies that it originated either with Pascal or in discussion with other members of the academy (2003: 40).

‘combinatio’ and ‘combination’ to mean. The consequence of using a single, undefined term for two concepts in each book is that they are required to take on a number of meanings. Initially, ‘combination’ and ‘combinatio’ are used to represent the number of permutations of n discrete objects, calculated using $n!$. This use is seen most clearly in the table of permutations of 23 to 64 discrete objects in both books (1636a: 116–17; 1965c: 109–10). In order to distinguish it from the other types of ‘combination’, this simple permutation, which acts as the building block for all permutations and combinations, is referred to elsewhere as the ‘combination ordinaire’ and the ‘ordinaria combinatione’ (1965c: 107; 1636a: 123). Mersenne stretches the meaning of the term further by applying it, in a second use, to the calculation of permutations with repeated objects, which is carried out by dividing two ‘ordinary combinations’ (1636a: 133; 1965a: 129).

A third use of ‘combinatio’ and ‘combination’ is for permutations of r notes selected from the n notes available. Mersenne presents this use of ‘combination’ for ‘permutation’ in the *Livre des chants* as ‘plus grande et plus generale que la precedente, qu’elle contient’ [larger and more general than the previous one, which it contains] (1965c: 131). In the *Liber de cantibus*, he simply states that that ‘[d]iffert igitur hæc combinatio à præcedente’ [this combination is therefore different to the previous one] (1636a: 133*). Mersenne demonstrates this new technique to find the number of permutations of eight notes from the triple octave of twenty-two notes by multiplying together the first eight natural numbers from twenty-two downwards (1965c: 131).[138]

Mersenne’s fourth use of the cognate terms in the two books is to calculate permutations where all of the notes available can be repeated as often as desired (in n^r different ways). He introduces this ‘combination’ too as a more general version of the ‘combination ordinaire’, on this occasion calling it ‘la plus generale de toutes’ [the most general of all] in the *Livre des chants* and the ‘Generalissimam Combinationem’ [Most general Combination] in the *Liber de cantibus* (1965c: 135; 1636a: 139). The final use of the terms ‘combination’ and ‘combinatio’ is for what we now refer to as ‘combinations’, rather than ‘permutations’. He introduces this last type in the *Livre des chants* as ‘cette particuliere combination’ [this particular combination], where ‘l’on ne fasse point

---

[138] The general formula for permutations gives the number of permutations as $P_8^{22} = \frac{22!}{(22-8)!} = \frac{22!}{14!} =$ $12{,}893{,}126{,}400$. Mersenne found the same result by multiplying the natural numbers from 22 down to 15.

les varietez qui procedent des differents lieux' [the varieties that come from different places are not made] and opposes it to permutations, where additional arrangements (or 'varietez') are permitted (1965c: 132).

Mersenne's use of the terminology of combinatorics in the *Livre des chants* and *Liber de cantibus* is clear in one respect but less so in another. His decision to use 'combination' for any number of objects fits well with standard contemporary practice, as Bernoulli notes (1795: 54). However, his decision to dispense with 'conjonction' for 'permutation' causes unnecessary problems, which he only partly solves by adding adjectives of generality and particularity to the term to differentiate between combinations and different types of permutation. In addition, examination of the terminology of permutations and combinations shows characteristics similar to the use of other mathematical terminology: the common usage of terms to support similar, but non-identical expositions of mathematical concepts in the two books. As with other mathematical terminology, the passages of text containing cognate terms for permutations and combinations convey the same concepts, but are not linguistically equivalent.

What is true of both types of mathematical terminology used in the two books is also true of the phrases of mathematical rhetoric deployed by Mersenne throughout both books: the phrases produce an equivalent effect but, because they are generally used in different contexts, neither could be said to be a faithful translation of the other. Instead, they are used to create texts of a similar nature on the same subject. The most common type of phrase of mathematical rhetoric Mersenne uses in both texts relates to the ease with which a given concept can be understood, and the way in which an example will bring clarity. He uses phrases of this type far more frequently in the *Livre des chants* than in the *Liber de cantibus*, persuading and reassuring the French readers that his arguments are correct in ways that the readers of the Latin text do not need, in the same way as Hérigone was seen to do in chapter 3. One example of this type of phrase appears in both books in the context of the same mathematical concept: the number of arrangements of a set of notes where all are to be used and none repeated. In the *Livre des chants*, the reader is told that 'il est si aisé de trouver le nombre de ces chants, qu'il n'est pas quasi besoin d'en expliquer la maniere' [it is so easy to find the number of these songs that there is barely any need to explain how] (1965c: 107). In the *Liber de cantibus*, the same sentiment is expressed in the following manner: 'facile vero reperitur ista varietas' [in truth, this variety is easily discovered] (1636a: 116). While these two phrases may be considered as approximately synonymous, this is a rare moment of equivalence between the two books.

As this last example shows, the use of mathematical language, whether terminology or phraseology, is very similar in the *Livre des chants* and *Liber de cantibus*. Crucially, it is not exactly the same in the two books, implying again that neither book can be considered a single original text from which the other was translated. Many cognate terms and phrases are used in the two books, including terms describing their components, terms describing mathematical concepts, and phrases of mathematical rhetoric. What is clear is that the words and phrases are not used as exact textual equivalents of each other. Although many cognate mathematical terms and phrases are used in both books, not all potentially equivalent terms and phrases appear in both books and, when they do, do not always describe precisely the same phenomena in exactly the same way.

The overall impression given by the use of mathematical language is that it has been deployed in the *Livre des chants* and *Liber de cantibus* to create two similar but non-identical texts of different lengths for different audiences, organised in different ways, dealing with very similar topics, and with a great deal of overlap between them. This was also the impression created by Mersenne's demonstrations and generalisations and his use of large numbers and mathematical tables, as outlined above. As I will demonstrate below, one of the features of Mersenne's use of a variety of references to his own works and, to a lesser extent, the work of established authorities, is to reinforce the notion that the two texts, and the larger works of which they form a part, are original companion volumes and that neither can be said to be an 'original' or 'translation' in the traditional narrow senses of the terms, as discussed in section 1.1. Moreover, it will also become clear that the individual books and the larger works to which they belong are intended to be seen as part of Mersenne's entire written works on music and mathematics.

4.3.5 Citation and self-citation

Natacha Fabbri characterises the inclusion of ‘quotations of classics [and] references [...] to his previous treatises’ as typical of Mersenne’s expository style, but does not explore his motivation (2007: 292). Analysis of Mersenne’s references to his own works and the works of authority figures suggests that they serve two principal functions: both citation and self-citation contribute to establishing Mersenne’s status as an expert in his field while self-citation, used as cross-referencing, helps represent his work on music and mathematics as an interconnected whole. Mersenne’s use of citation and self-citation stands in contrast to the practices that can be identified in the other two case-study works. As was noted in chapter 3, Hérigone names some, but not all, of the mathematicians whose work he uses in his compilation and includes a history of mathematical contributions in his chronicle in volume six of the *Cursus*, but does not cite his own work. As will be seen in chapter 5, Pascal does not refer to most of the many previous contributors to the work on the Arithmetic Triangle (including work on permutations, combinations, number sequences, and binomial expansions) in his treatises, restricting himself to citing two seventeenth-century mathematicians as a means of avoiding going into greater detail in his mathematical explanations.

In his analysis of modern academic articles, Ken Hyland suggests that self-citation functions as part of a rhetorical strategy to strengthen a scholar’s credibility and standing in their discipline (2003: 251). Although Hyland’s research focuses on self-citation alone in a different era and a different genre, it accurately describes the first aspect of Mersenne’s use of citation. Throughout both the *Livre des chants* and the *Liber de cantibus*, Mersenne refers to a range of authorities. In both books, he mentions scholars and writers both ancient, including Ancient Roman and Ancient Greek authorities, and more modern, including scholars from both the Middle Ages and the Renaissance, along with references to the Bible. Most of the references are not the same in the two books. For example, most of those in the *Livre des chants* are to what Mersenne calls ‘les Anciens’ [the Ancients] (1965c: 156): Greek and Roman writers and scholars including Aristotle and Plutarch (before 50–after 120 CE) (1965c: 98), and Cicero and Xenophon (*c.* 430–*c.* 355 BCE) (1965c: 103), as well as the Bible (1965c: 101, 102, 104, 139, 142). There are also references to more modern scholars, such as musicologist Domenico Pietro Cerone (1566–1625) and composer Claude Goudimel (*c.* 1514–1572) (1965c: 96–97, 161). The types of authorities cited in the *Liber de cantibus* are similar to those in the *Livre des chants*, but the specific scholars referenced are largely different: Greek and Roman writers and scholars such as Pythagoras, Terence (195–159 BCE), Xenocrates (396–314 BCE), Epicurus (341–270 BCE) (1636a: 119) and Pliny the Elder (23/24–79 CE) (1636a: 124), and Christian scholars such as St. Augustine (1636a: 114). As with the *Livre des chants*, modern scholars are also cited, including Kepler, classical scholar Caelius Rhodiginus (Lodovico Ricchieri, 1469–1525), polymath Johannes Trithemius (1462–1519) and linguist Johannes Goropius Becanus (Jan Gerartsen, 1519–1573) (1636a: 115, 119). Despite the differences noted above, some authorities cited by Mersenne are common to both books, including Euclid (1965c: 91; 1636a: 115), Homer (eighth century BCE) (1965c: 105; 1636a: 115), Plato (1965c: 103; 1636a: 119), rhetorician Julius Pollux (*fl.* 170 CE) (1965c: 161; 1636a: 115), painters Protogenes (*fl. c.* 300 BCE) and Apelles (*c.* 370–early third century BCE) (1965c: 104; 1636a: 124), and historian Jules-César Boulenger (1558–1628). The references to Boulenger are unusual in the sense that they are linguistically very similar in the two books: 'le 52 chapitre du premier livre que Bullenger a fait du Theatre' [chapter 52 in the first book that Boulenger wrote on the Theatre] (1965c: 161) and 'Bullengerus lib. I. de Theatro' [Book 1 of Boulenger's *De theatro*] (1636a: 115). It is likely that Mersenne chose his references carefully, with his different audiences in mind: some of the references provided in the *Liber de cantibus*, including Trithemius and Rhodiginus, are unlikely to have been known to a less scholarly audience, for example.

Although many of the authorities cited in the two books are different, they do serve the same purpose: to lend authority, both intellectual and religious, to Mersenne and his work. In both books, Mersenne is clearly keen to position what he considers to be his musical masterpiece in a number of traditions, stretching from antiquity to his own day, by citing highly respected mathematicians, philosophers, historians, musical theorists and composers, and a range of other scholars. Fabbri's comment suggests that this is a practice Mersenne repeated in all of his works. The impact in self-translation terms is the same as in the previous sections of this chapter: the general lack of overlap between both the authorities referenced and the manner in which they are cited reinforces the conclusion that the *Livre des chants* and the *Liber de cantibus* are both original texts. However, the overlap in some of the authorities and in the type of authorities invoked — classical and modern writers and scholars of astronomy, music and the arts, amongst other disciplines — suggests that the two books can be considered to be versions of the same work.

In addition to citing a range of authorities, Mersenne cites his own works in the *Livre des chants* and *Liber de cantibus*. These self-citations are of four main types, and all act to differing degrees as types of cross-reference: internal references to other propositions in the book in question, references to other books in the same collection, references to his own previous works, or references to the other book in the pair. The main function of these self-citations is to support a point Mersenne is making by drawing on his own expertise from elsewhere in his published works. Such, for example, is the case with his reference, in proposition XIV of the *Liber de cantibus*, to his works on secret writings in the 'secundo volumine in Genesim' [second volume of the *Quæstiones in Genesim*] and the 'libris Harmonicis Gallice' [French book on harmonics, i.e. the *Harmonie universelle*] (1636a: 140). The implication is that the reader will need to acquire and consult the *Quæstiones in Genesim* and the *Harmonie universelle* alongside the *Liber de cantibus* in order to gain a full understanding. The self-citation therefore works alongside the citations of authorities to establish Mersenne as an eminent scholar in the field of music. It also serves both to promote Mersenne's other works and to suggest that he sees a significant proportion of his potential audience as bilingual and therefore able to read works written in both Latin and French.

The sense that Mersenne views his exposition of combinatorics in his works on music and mathematics as an interconnected whole can be seen very clearly within the *Harmonie universelle* and *Harmonicorum libri* in the way in which he cites each of the *Livre des chants* and *Liber de cantibus* in the other text. Each citation in both books refers to information that is not included in the book containing the reference but is included either in the other book or the collection to which it belongs. At the end of proposition XIV in the *Liber de cantibus*, for example, Mersenne states that '[c]ætera libris Gallicis et libro de Voce dicturi sumus' [We will refer to the rest in the French book and the *Livre* *des voix*] (1636a: 140). Similar comments can be found in the *Livre des chants*, such as when, in presenting the Arithmetic Triangle, he states that 'j'ay donné la maniere de la construire dans la 12 proposition du livre Latin des chants' [I showed how to construct it in the twelfth proposition in the *Liber de cantibus*] (1965c: 145). While Mersenne subtly implies in these comments that he feels no need to repeat mathematical techniques he has demonstrated elsewhere, he is very explicit about his decision in the *Livre des chants* not to repeat the techniques to find permutations from the *Liber de cantibus*, saying that 'j'en ay traité dans le livre des varietez de l'Octave, [...] et dans la 5 proposition du 7 livre Latin des Chants, c'est pourquoy je ne la repete point icy' [I have dealt with it in the book on the varieties of the Octave, (...) and in the fifth proposition of the seventh Latin book, on Songs, which is why I'm not repeating it here] (1965c: 110). These examples suggest that the book referred to includes information that is unique to that book but important for understanding of the other book in the pair. The implication is that the *Livre des chants* and *Liber de cantibus* are separate but interconnected books that should be read together (or at least kept for reference alongside each other). Mersenne is again using self-citation as a marker of authority, confirming the importance of all of his work to a full understanding of the ideas contained within them.

The main finding in this section echoes the main finding throughout the comparison of the Latin and French books on songs: although they show a high degree of similarity, there are significant differences between them. The similarities and differences at all levels suggest that the books are dual, complementary originals and that neither book can be considered the sole original and neither a secondary, translated version of the other. The way in which this finding fits with overall consideration of the *Harmonie universelle* and *Harmonicorum libri* will be dealt with in the conclusion.

4.4 Chapter conclusion

Mersenne's decision to compile the *Harmonie universelle* and *Harmonicorum libri* in both French and Latin, the two languages in which he wrote his scholarly works and corresponded with his peers, can be seen as a result of both his own, personal view of the centrality of the books to his scholarly output and of macro-level historical forces, particularly the development of audiences caused by changes in the languages used in scholarly works, improvements in education and the creation of the Republic of Letters. At a personal level, the *Harmonie universelle* and *Harmonicorum libri* stand out in Mersenne’s published work as the only pair of works published in both languages, his ‘grand œuvre de la Musique’, the product of ten years’ work, as he told Peiresc. At the macro-level, Mersenne’s writings were published between 1623 and 1651, during the period, identified by Fransen and Blair and highlighted in chapter 2, when the proportion of scholarly books published in Latin across Europe, including France, began to undergo significant change. This was the period when French first stood alongside Latin as its peer for use in science, before later eventually superseding it. The choice of language for all scholars at this juncture reflected the intended audience for a work: Mersenne’s choice of languages can therefore be explained by his appreciation of the most likely audiences for each of his works. The books that were of Europe-wide interest, such as the *Quæstiones in Genesim* and the scholarly mathematical collections, were written in Latin mainly with the scholars of the Republic of Letters in mind, while the works intended for domestic consumption, including most of the early works on religion and belief and the translations introducing Galileo’s science to France, were published in French for French scholars and for the small but growing educated audience discussed in chapter 2. Mersenne’s appreciation of his audiences can also be seen in his correspondence: he wrote in French to communicate with correspondents with knowledge of French, whether or not they were French, reserving Latin for those with little or no understanding of the language. Mersenne clearly envisaged two principal audiences for the *Harmonie universelle* and *Harmonicorum libri*, one at home and one abroad, as demonstrated by his comment to Peiresc that he had written a Latin ‘compendium’ of French music for foreigners, based on the longer French version.

Mersenne’s comment on the two works opens up questions about the relationship between them. Can the *Harmonie universelle* be considered the original work and the *Harmonicorum libri* an abridged or translated version of it? Or should they be viewed as dual original versions of the work, of different lengths? Mersenne’s description of the *Harmonicorum libri* as a shorter musical ‘compendium’ of the longer French work cannot simply be taken to imply that he considered it to be an abridged version of the *Harmonie universelle*, despite initial appearances. Close comparison of the two works does confirm that, while there is a strong degree of correspondence between them at the level of their structure and content, the *Harmonicorum libri* is shorter than its French equivalent, and contains fewer books: some books in the *Harmonie universelle* have no equivalent in the *Harmonicorum libri*, while there are books in the Latin work that cover the content of more than one French book, and in reduced format. Moreover, where there are directly equivalent books, those in the Latin work are generally shorter than the French equivalents, and generally contain fewer propositions. Despite the evidence to support the case for the *Harmonicorum libri* to be viewed simply as an abridgement of the *Harmonie universelle*, however, the presence of original material in the Latin work that is not found in the *Harmonie universelle*, such as Matan’s work on combinatorics, suggests a more complex relationship.

As dual versions of Mersenne’s great work on music, the *Harmonie universelle* and *Harmonicorum libri* are clearly an example of simultaneous self-translation, the bilingual texts having been written alongside each other, each influencing the development of the other, in line with Grutman’s definition (2019: 516). As simultaneous self-translations, they cannot be defined using standard notions of original and translation, and so, in Bassnett’s terms, should be viewed as twin original versions of the same bilingual work (2013a: 288). Furthermore, the presence of original material in the *Harmonicorum libri* implies that both the *Harmonie universelle* and *Harmonicorum libri* should be viewed not simply as dual original works, but as complementary original works on the same subject in different languages.

This perception of the *Harmonie universelle* and *Harmonicorum libri* as dual complementary works on the same subject is reinforced by closer examination of one pair of equivalent books: the *Livre des chants* and *Liber de cantibus*. This analysis reveals that the books on songs largely manifest the same kinds of similarities and differences as the *Harmonie universelle* and *Harmonicorum libri* as a whole: there is a large degree of overlap in mathematical content and in the structure of the books and their component parts, but the differences between them are sufficiently significant to conclude that the books should be considered as complementary, companion volumes. The overall structure of the two books is very similar, and closer examination of both the detail of the structure and the order of the propositions shows a good deal of commonality but not enough for either the *Livre des chants* or the *Liber de cantibus* to be classed as the original text. This picture of a degree of overlap but incomplete correspondence is reinforced by the use of tables: many are the same in the two books, while some appear in only one book, and there are inconsistencies in their relative ordering. The same overall impression is given by the content and its exposition: the main mathematical content involving combinatorics is very similar, the examples demonstrating how the concepts relate to the books' musical themes have a similar purpose in the two books, the same sense of wonder at large numbers is conveyed, many cognate terms and phrases of mathematical rhetoric are used, and there are references to many of the same authorities in the two books. However, despite the common content, terminology, style and purpose, there are major differences between the books in a number of respects: in the actual examples used, the level of detail in demonstrations, and the sophistication of the language used, for example. In addition, Mersenne tells the reader of each book that additional material can be found in the other book. This strongly implies that, in order to gain a full picture of Mersenne's work on songs, the reader will need to read both the *Livre des chants* and *Liber de cantibus*. This complementarity does not, however, mean that Mersenne treated the audiences for the two books, and, by extension, the works to which they belong, in precisely the same way. There is clear evidence that he had higher expectations of the mathematical ability of the readers of the Latin book than of those of its French counterpart: he included Matan's theoretical work in the Latin book alone, drew more general conclusions from his examples, provided abstract titles in titles of tables, made more scholarly references, and used more technical terminology, such as conternations and conquaternations, in the *Liber de cantibus*, but not the *Livre des chants*. In addition, Mersenne provides a greater level of explanation in demonstrations to facilitate understanding of concepts for readers of the French book.

Further statements made by Mersenne in the two books suggest that he saw them as complementary not just to each other, but to the other books in the

Harmonie universelle and *Harmonicorum libri* and, to a lesser extent, to other books in his scholarly output: he refers in both books to material that the reader is required to find in other works, in order to make full sense of the books. Unfortunately, there is insufficient information in archives such as the CERL's HRB database to suggest that any of Mersenne's readers had copies of both the *Harmonie universelle* and *Harmonicorum libri*: none of the books currently held in the research libraries have the same provenance. De Gaignières's letter provides a further small indication: he only had the Latin work, with fewer books, and enquired whether Mersenne intended to have the other books printed (De Gaignières 1960: 193). There is no suggestion that he would obtain either the full *Harmonie universelle* or the French versions of the missing Latin books, even though most of the individual books in the *Harmonie universelle* were printed and sold separately. De Gaignières's enquiry notwithstanding, all of the existing evidence about the two works that I have collected in this chapter confirms the hypothesis with which it opened: that the *Harmonie universelle* and *Harmonicorum libri* are complementary versions of Mersenne's major musical work, dual original parts of a bilingual work conceived and composed together, where neither version has primacy, despite the greater length of the French version.

Chapter 5

Blaise Pascal: the treatises on the Arithmetic Triangle

Blaise Pascal's bilingual works, the *Triangulus arithmeticus* and the *Traité du triangle arithmétique*, are the principal treatises in two collections of treatises in which he outlined the main properties of what he termed the 'Arithmetic Triangle' and what is most frequently known today as Pascal's Triangle.[139] As will be shown below, the *Traité du triangle arithmétique* was written shortly after the *Triangulus arithmeticus* in 1654 as Pascal continued to develop his understanding of the Arithmetic Triangle. Most of the other treatises in the two collections were also written in 1654. The first, unpublished collection of treatises, which includes the *Triangulus arithmeticus*, consists of treatises written solely in Latin, while the second, which was published as the *Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière* in 1665, is a mixture of French versions of some of the Latin treatises, new treatises in French, and the remaining original Latin treatises.[140]

Although the Arithmetic Triangle is well known within mathematics, there has been very little original research into the treatises in either collection within either the history of mathematics or Pascal studies. This lack of research may be attributed to a number of factors that will be dealt with in more detail below: Pascal's own failure to ensure that either collection of treatises was distributed during his lifetime, the fact that much of the work in the principal treatises was largely unoriginal and was overshadowed by the more innovative work Pascal undertook in collaboration with Fermat, and the fact that his contribution to probability theory was quickly superseded by the research of other mathematicians. These same reasons may also explain why it took so long before the existence of the *Triangulus arithmeticus* as the original Latin version of the *Traité du triangle arithmétique* was recognised and why neither the

[139] The 'Triangle arithmétique' is variously translated as 'Arithmetic Triangle' (by Richard Scofield and Anna Savitsky in their translations of the principal treatise in Pascal 1952b and Pascal 1959 respectively) and 'Arithmetical Triangle' (by Edwards, 1987, 2003 and 2013, and David Pengelley, 2009). I have chosen to call it the 'Arithmetic Triangle' throughout this chapter because the adjective 'arithmetic' is used more frequently than 'arithmetical' in mathematical terminology, such as in the terms 'arithmetic mean' and 'arithmetic progressions' (alongside 'geometric mean' and 'geometric progressions').

[140] The published collection of treatises will be referred to in this chapter by the slightly shorter title of *Traité du triangle arithmétique, avec quelques autres petits traités* to differentiate it from its principal treatise.

collections nor their principal treatises have ever been the focus of research within translation studies.

The lack of research in general was acknowledged in 2008, when Descotes noted that '[e]n dehors des travaux classiques de Kokiti Hara, de Jean Mesnard et de A.W.F. Edwards, le *Traité du triangle arithmétique* est assez peu étudié' [apart from the classic works by Kokiti Hara, Jean Mesnard and A. W. F. Edwards, relatively little attention has been paid to the *Traité du triangle arithmétique*] (2008: 239).[141] Descotes himself should be added to this list following publication of three original articles on the treatises dealing with the Arithmetic Triangle (2001b, 2008, 2020). Within the study of the history of mathematics, Edwards's 1987 work superseded all previous research into Pascal's work on the Arithmetic Triangle, including in particular three articles written in the early twentieth century by Henri Bosmans (1906, 1923,1924).[142] Neither Edwards nor Bosmans acknowledges the existence of separate collections of treatises, both dealing solely with the second, published collection, so their research has no direct bearing on my research into Pascal's self-translation. Their work is nevertheless important in establishing the context within which the treatises were written. Both scholars investigate the history of the mathematical ideas in the treatises, reflect on the attribution of the Arithmetic Triangle to Pascal in modern mathematics, and 'translate' Pascal's text into modern mathematical notation.

Within Pascal studies, Mesnard's focus is on the history of the writing, printing and publication of the two collections of texts and is still considered the definitive account (1964b, 1970b), although Edwards disagrees with some of Mesnard's conclusions. The publication history of the treatises is also part of Descotes's area of interest, though his work in this area is mainly a summary of Mesnard's findings (2001b, 2008), combined with new research (2020). His main focus is on the collections as literary works (1988, 1993, 2001a, 2001b). The work of the final scholar mentioned by Descotes, Hara, straddles both the history of mathematics and Pascal studies: he investigates both the history of

[141] It should be noted that, although Descotes only mentions the principal treatise from the French collection, examination of the works of the authors cited shows that he was clearly referring to research into all of the treatises on the Arithmetic Triangle.
[142] According to Edwards, the only treatment of the subject before publication of his work were sections in German books on Leibniz and elementary mathematics and Bosmans' 'somewhat inaccessible account' from 1906 (1987: x–xi).

mathematical induction (1962) and the composition of the two collections (1981a). Mesnard, Hara and Descotes all compare the relative structures of the two collections to identify which works were translated, either wholly or in part. However, very little of their work probes more deeply into matters related to translation or self-translation. Hara briefly speculates on Pascal's motivation for translating parts of the original work (1981a). Descotes takes a closer look at some aspects of the translation of the principal treatise, but, as well as focusing on the comparative structures of the collections, he is principally interested in the translation of mathematical ideas between the two collections, from a literary perspective, as he states himself (2001b: 49).

The main focus of this chapter — an investigation into the *Triangulus arithmeticus* and *Traité du triangle arithmétique* and the collections to which they belong as examples of bilingual writing — will therefore cover new ground. The reasons why Pascal wrote two versions of the treatises can only be understood within a range of wider contexts: Pascal's general writing practices, the wider social, intellectual and linguistic context within which he was working, and the collections for which the *Triangulus arithmeticus* and *Traité du triangle arithmétique* provide the introductory and most important texts. This research will therefore need to consider a range of questions in each of these more general areas, prompted by the research on self-translation discussed in chapter 1, before focusing more specifically on questions relating directly to the principal treatises themselves. The following questions will therefore be considered first: how do the collections and their principal treatises fit into Pascal's complete written works, particularly his scientific and mathematical writings? What do his complete written works reveal about his choice of languages? Are there any other self-translated works in Pascal's writings? If so, what light do they shed on the treatises on the Arithmetic Triangle? Does Pascal show a preference for French or Latin in his works, and does this depend on the context? How can his language selection be explained by considering the use of French and Latin in mid-seventeenth-century France and Europe? In order to answer these questions, section 5.1 will set Pascal's works on the Arithmetic Triangle in the context of his life and his work as a mathematician and scientist, with particular emphasis on his use of languages and self-translation.

Once account has been taken of Pascal’s writing practices and the wider historical and social context, a number of questions will be considered with regard to the two collections of treatises on the Arithmetic Triangle. Can the second collection be considered a self-translated version of the first if it contains treatises in French that were not in the original collection and if some of the original Latin treatises do not have French versions? In order to answer these questions, I will summarise the research comparing the two collections, against the background of Pascal’s work on probability.

Consideration of these questions will then lead to a range of further questions relating specifically to the *Triangulus arithmeticus* and the *Traité du triangle arithmétique*. Is the French version of the principal treatise simply a faithful translation of the Latin original, or did Pascal’s continued development of the Arithmetic Triangle after he completed the Latin version have an impact on the French version? Irrespective of the degree of conformity with the Latin version of the treatise, can the French version be said to stand as a second original, separate and independent from the Latin version? Can either version be said to have primacy over the other in terms of status and renown? Do the conclusions about the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* have an impact on the conclusions about the collections as a whole? The rest of the chapter will therefore focus on a comparison of the texts of the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* at a number of levels: a comparison of the most important structural features of the principal treatises, followed by a study of Pascal’s rhetorical method and a comparison of the two texts. Section 5.3 will deal with the similarities and differences between the treatises’ mathematical structures, particularly the use of the diagram of the Arithmetic Triangle and the division of the treatises into two clearly defined sections. Section 5.4 will concentrate on Pascal’s treatment of terminological definition and mathematical demonstration in the light of his writing on the subject in the two parts of his theoretical work *De l’esprit géométrique*, written shortly after he completed the treatises on the Arithmetic Triangle.

5.1 Pascal's mathematical and scientific writings

Pascal is known today as a 'mathematician, physicist, religious philosopher, and master of prose' (Orcibal and Jerphagnon 2021). Pascal's work on mathematics and physics, both before and after 1654, when the treatises were composed, covered a range of subject matter. His philosophical writings, the best known of which are the *Lettres provinciales* [Provincial Letters] (1656–57) and the *Pensées* [Thoughts] (1661), deal mostly with his Christian belief and the religious philosophy of the Jansenists, a movement within the Catholic Church. Pascal first became involved with the Jansenists in 1646 and, following a significant personal incident in November 1654, became increasingly involved with their abbey at Port-Royal in Versailles (Rogers 2003: 14–18).[143] This second conversion, as it is known, had a profound impact on Pascal's mathematical work and, in the context of this thesis, on publication of the treatises on the Arithmetic Triangle, as will be seen in section 5.2.

Pascal was educated at home by his father Étienne, 'one of the leading mathematicians of his age' (Rogers 2003: 5). Étienne had been a prominent member of the *noblesse de robe*, the class of government officials who traditionally ran the French state. When he sold his government position, he had the means to spend more time focusing on his own mathematical research and his son's mathematical education (Rogers 2003: 6). It also meant financial independence for Pascal when his own works were published. Pascal showed early promise in mathematics, which led his father to introduce him to the group of mathematicians around Mersenne (Rogers 2003: 6; Adamson 1995: 2). With the prompting of Mersenne's circle, Pascal began his mathematical and scientific research, publishing a short work on projective geometry, the *Essai pour les coniques* in 1640, at the age of sixteen (Taton 1981b: 330). Pascal continued with mathematical and scientific research throughout the rest of his life. René Taton has identified five areas of mathematical and scientific research undertaken by Pascal over approximately a twenty-year period: projective geometry (1639–1654), mechanical computation (1642–1652), fluid statics and

[143] Letters between Pascal's sisters, Jacqueline Pascal (1625–1661) and Gilberte Périer (1620–1687), show that he had been feeling unfulfilled by his social engagements and mathematical and scientific work and that, in 1654, he began to seek spiritual counsel at Port-Royal. Suddenly, on 23 November that year, 'Pascal underwent an extraordinary spiritual conversion, in which [...] he felt the presence of God' (Rogers 2003: 14).

the problem of the vacuum (1646–1654), the calculus of probabilities and the Arithmetic Triangle (1653–1654), and the calculus of indivisibles and the study of infinitesimal problems, mainly related to the cycloid (1654–1659) (1981b: 330–37).[144] The year 1654, the year of Pascal's 'second conversion' and the year in which he wrote the *Triangulus arithmeticus* and the *Traité du triangle arithmétique*, can clearly be seen as a critical juncture in his life.

The publication status of Pascal's scientific and mathematical output is varied: although some work was completed and published in his lifetime, other work was begun but not completed, while yet more was completed but not printed or published until after his death. Mesnard believes that, throughout his life, Pascal had a tendency to throw himself into a topic — whether mathematical, scientific or philosophical — when he became interested in it, often working with the people around him to discuss aspects of the subject, only to move quickly on to the next interesting topic (1964b: 28). Fortunately for works such as the treatises on the Arithmetic Triangle, Pascal tended to write quickly when he was interested in a subject, so that, even if a work were not fully finished, it would generally be largely completed (Mesnard 1970b: 1171).

Pascal's way of working meant that only approximately a third of all his completed writings were printed during his lifetime (Mesnard 1964b: 27). This includes his work on mathematics and physics, a significant proportion of which was not published until after his death. The first five published works were printed in the period 1640–1651, the first being the *Essai pour les coniques*, which was not much more than a single-page handout for the members of Mersenne's circle (Mesnard 1964b: 29–30). This was followed by the *Expériences nouvelles touchant le vide* [New Experiments Concerning the Vacuum] (1647), and the *Récit de la grande expérience de l'équilibre des liqueurs* [Account of the Great Experiment on Equilibrium in Liquids] (1648), the only two of these early works to bear the name of a bookseller. The final two works were letters, one forming part of what Mesnard describes as the prospectus for the mechanical calculator Pascal invented (1645) and the other defending Pascal's reputation as a scientist. Pascal paid for small numbers of all five works to be printed and distributed them himself (Mesnard 1964b: 30).

[144] A cycloid is defined as '[t]he curve traced out by a point on the circumference of a circle that rolls without slipping along a straight line' (Clapham and Nicholson 2014: 115).

All of the other scientific and mathematical works printed and distributed during Pascal's lifetime related to the cycloid. Most were circulars concerning a competition that Pascal organised in 1658: three letters for distribution to mathematicians across Europe outlining the competition, the first two in Latin and the third in both French and Latin, and bilingual accounts of the outcome of the competition, the *Histoire de la roulette* and the *Historia trochoidis* [Account of the Cycloid] (both 1658), and the *Suite de l'histoire de la roulette* and the *Historia trochoidis continuatio* [Account of the Cycloid Continued] (both 1659). These are the only self-translations in Pascal's written works other than the bilingual treatises in the collections dealing with the Arithmetic Triangle; they will be discussed in section 5.2.2. The final publication on cycloids, the *Lettres de A. Dettonville*, printed in 1659, consisted of four letters written in the name of Amos Dettonville, one of Pascal's pseudonyms, to a number of other mathematicians, and contained treatises on the subject of Pascal's discoveries in this area of mathematics.[145] Of these works, only the Dettonville treatises were published through a bookseller and distributed in any numbers, though it was again Pascal who paid for the printing and distributed the printed treatises (Mesnard 1964b: 30–33, 1992b: 367).

The only mathematical work that was printed, but not distributed, during Pascal's lifetime contained the treatises concerning the Arithmetic Triangle (Mesnard 1964b: 33–37). A full account of the composition and printing of the treatises will be given in section 5.2.2 below. All of Pascal's other scientific and mathematical writings were either lost or published posthumously. Pascal's family ensured that any writings that were ready to print were published soon after his death (Mesnard 1964b: 43–48). These included the publication in 1663 of the *Traités de l'équilibre des liqueurs et de la pesanteur de la masse de l'air* [Treatises on the Equilibrium of Liquids and the Weight of the Mass of Air] (originally composed in 1654) and two fragments of a treatise on the vacuum (Mesnard 1964b: 43–44). Copies of some of his writings were found in Leibniz's papers after his death. The German mathematician had been asked by Pascal's family to prepare some of the remaining mathematical works for printing, but the project was never completed. The works included *Generatio conisectionum*

[145] Amos Dettonville is an anagram of Louis de Montalte, the pseudonym that Pascal used when he wrote the *Lettres provinciales*, and Salomon de Tultie, a pseudonym that he referred to in the *Pensées* (Mesnard 1964b: 33). In both cases, the interchangeability of the letters 'u' and 'v' in seventeenth-century type needs to be taken into account.

[Generating Conic Sections], part of a geometric treatise, and the *Introduction à la géométrie* [Introduction to Geometry], part of a book that was never completed. It also included the *Celeberrimæ matheseos academiæ Parisiensi* [To the Illustrious Parisian Mathematical Academy], an address Pascal made in 1654, in which he introduced a number of projected works, including a significant planned work on probability, the *Aleæ geometria* [The Geometry of Chance] (Mesnard 1964b: 53–55; Adamson 1995: 34–35). Many of the projected works have either vanished or were never written (Adamson 1995: 33). Further works have been discovered in the intervening years, including an exchange of letters with Fermat, which was first published in Fermat's *Varia opera mathematica* [Various Mathematical Works] in 1679, and the two treatises that make up *De l'esprit géométrique* and encapsulate Pascal's thinking on the mathematical method, as will be seen in relation to the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* in section 5.4 below (Mesnard 1964b: 67).

It can be seen from the information above that Pascal produced a range of scientific and mathematical works in his lifetime, even if they were not all completed or published before he died in 1662. Approximately half of the works were written solely in French. The rest were written either solely in Latin or in both French and Latin. If the mathematical and scientific works are examined separately, however, two significant trends become clear: all of the writings on physics were composed in French alone, while all of the works that were written either wholly or partly in Latin are mathematical in nature. The works that Pascal composed solely in Latin were the first two letters concerning the cycloid competition and the incomplete and unpublished *Generatio conisectionum* and *Celeberrimæ matheseos academiæ Parisiensi*, while the accounts of the cycloid competition and one of the letters announcing it were written in both Latin and French. It would seem highly likely that the reasons for publishing these latter writings as bilingual works were determined by the two audiences for the competition, the Europe-wide Latin-educated mathematicians who would mostly have been the intended audience for the Latin versions (Mesnard 1964b: 30), and their counterparts in France, who would have been able to access either volume. This conclusion suggests that Pascal's choice of languages in his writings was largely pragmatic. Certainly, I can find no evidence that he ever expressed a view of the relative merits of the two languages in his writings. We know from the *Vie de Monsieur Pascal* written by his sister Gilberte Périer that he learnt Latin before beginning his mathematical education (1964: 572–73) and Donald Adamson concludes that he was an equally fluent writer in both languages (1995: 175). This fluency allowed him to choose freely between the two languages when writing.

This survey of Pascal’s written works and the more relevant aspects of his biography have shed light on the first set of questions posed in the introduction to this chapter. The mix of Latin and French in the collections of treatises as a whole is typical of Pascal’s written mathematical output, both published in his lifetime and following his death. Although his religious, philosophical and scientific works were all written in French, his mathematical works were written in a mixture of Latin and French to suit both the context and projected audience or audiences. Moreover, Pascal’s only other self-translated works — relating to the cycloid competition — were also mathematical. Their existence as documents recording a Europe-wide competition demonstrates Pascal’s understanding of the different audiences for his mathematical works. The reasons for writing in Latin were historical and geographical: as was seen in chapter 2, Latin had been the *lingua franca* for science and mathematics across Europe for centuries and had not yet lost that status. This pan-European intellectual community would have been part of the intended audience for the Latin-only collection of treatises on the Arithmetic Triangle. The members of the new informal scientific and mathematical academies were part of this Europe-wide intellectual community and so were able to discuss and read and write about them in either Latin or French: theirs was a truly bilingual community. The first collection of treatises would have been written for them too, though they would of course have been able to gain access to the mathematical ideas contained in them using the second, mixed Latin and French collection as well. French was the language of the Parisian salons that Pascal is known to have briefly attended between 1652 and 1654 (Adamson 1995: 42–43). In particular, he is known to have attended the salons to popularise both science and mathematics: his presence at a salon in 1652 is mentioned in a poem written by

Jean Loret and published in his gazette, the *Muse historique* (1970: 903).[146] Pascal's presence in the salons as a populariser of science and mathematics in the years before he wrote the treatises on the Arithmetic Triangle may go some way to explaining why he translated the more accessible and practical parts of the first collection into French.

The proximity of Pascal's appearance at a salon popularising mathematics in 1652 to the publication in both Latin and French of the collection of treatises relating to the Arithmetic Triangle is unlikely to be completely coincidental. Along with the correspondence with Fermat, the treatises represent Pascal's contribution to probability, or 'the Geometry of Chance', as he described it himself in the address to the Parisian Academy. Section 5.2 will examine Pascal's contribution to the founding of modern concepts of probability and the ways in which his work on probability led him to write the two collections of treatises.

5.2 Pascal, probability and the treatises on the Arithmetic Triangle

5.2.1 The 'Geometry of Chance': Pascal and the foundations of probability

Pascal is generally considered to be 'the first significant figure in probability theory' (Hacking 1975: 61), because he introduced 'entirely new mathematical techniques [...] which became the foundation of the modern theory of probability' (Edwards 2003: 40). The distinction of founder of probability is partly shared, as '[t]he modern theory of probability is usually considered to begin with the correspondence of Pascal and Fermat in 1654' (Katz 2014: 489).[147] It was Pascal's initiative that led to the breakthrough in the

[146] The *Muse historique* [Historical Muse] was '[a] weekly gazette in doggerel verse by Jean Loret; it takes the form of gossipy epistles about social and artistic life between 1650 and Loret's death in 1665' (France 1995: 550). In the poem, Pascal is said to have demonstrated 'les effets merveilleux / D'un ouvrage d'arithmétique / Autrement de mathématique' [the marvellous effects of an arithmetic, or mathematical, work] (Loret 1970: 903). This was probably a reference to Pascal's mechanical calculator (Mesnard 1970c: 902).

[147] What was new in the correspondence between Pascal and Fermat was a clear understanding of the mathematics of expectation (Hacking 1975: 92). Before this, no mathematician had formulated a clear idea of probability or expectation, or their usefulness in tackling practical problems (Huber 2009: 1336–37). For the first time, systematic methods were used for tackling a problem involving chance (Bernstein 1996: 63). This involved looking forward, to consider future events, rather than looking back at what had already happened, as had been the case up to the point where Pascal and Fermat began their correspondence (Huber 2009: 1336). There is some disagreement about the relative contributions of the two mathematicians, with Florence David seeing Fermat as the greater contributor (1962: 95–97), and disagreement about the importance of their contribution overall to the foundation of probability theory, with Leonid Maïstrov believing it to have been 'overestimated' (1974: 55).The majority of historians of

understanding of probability: the correspondence between the two mathematicians was prompted by a question that Pascal was asked by one of his acquaintances, Antoine Gombaud, the Chevalier de Méré (1607–1684), regarding the so-called 'problème des partis', or 'problem of points' (Singh 1998: 43–44; Katz 2014: 469).[148] Pascal and Fermat both found solutions to the problem, using different methods (Huber 2009: 1337–38).[149] One of the methods used by Pascal is outlined in the *Usage pour les partis*, one of the smaller treatises found solely in the French collection.

The solution to the problem of points and completion of the *Traité du triangle arithmétique* was the culmination of approximately sixteen months of work on probability by Pascal, up to September 1654 (Adamson 1995: 33). As mentioned above, in his address to the Parisian Academy earlier in 1654, Pascal had announced that he intended to bring together all of his work on probability into a single 'astonishing' work called the *Aleæ geometria* that included elements that eventually formed part of the *Traité du triangle arithmétique*, and other works that were either never written or were subsequently lost (About and Boy 1983: 8; Adamson 1995: 33–35).[150] In his address, given in Latin, Pascal presented the probability work as '[n]ovissima

---

mathematics share the views of Ian Hacking, Edwards and Adamson regarding the importance of Pascal's contribution, with and without Fermat. See, for example: Simon Singh (1998: 43), Alfred Rényi (1970: 54), Ian Stewart (2012: 111), Merzbach and Boyer (2010: 334), Katz (2014: 489), Peter Bernstein (1996: 63), Pierre-José About and Michel Boy (1983: 21), Pengelley (2009: 185), Glenn Shafer (1994: 1293), Isaac Todhunter (1865: 7), Lorraine Daston (1980: 236), Keith Devlin (2008: 2), and William Huber (2009: 1336–37).

[148] The problem of points involves determining the share of stakes for players in games that are not completed for one reason or another. The problem was not new: there is evidence of its existence in various forms since the end of the fourteenth century (Meusnier 1995: 18), and possibly as far back as the thirteenth century (Huber 2009: 1336). The problem had been tackled by a number of Italian mathematicians during the Renaissance, including Pacioli, Tartaglia, and Cardano, but none achieved a full solution (Mankiewicz 2000: 154). The mathematician who came closest was Cardano: he published a solution similar to Pascal's in his *Practica arithmetica* [Practice of Arithmetic], published in 1539, but this seems to have gone unnoticed, and expanded on it in his *De ludo aleæ* [On Games of Chance], which was written in the 1520s but not published until 1663, after the correspondence between Pascal and Fermat took place (Franklin 2001: 298).

[149] General practice at the time was to discuss a mathematical problem with other scholars in the academy, or to engage in correspondence with other mathematicians (Bernstein 1996: 61). There is evidence from his letter to Fermat dated 29th July 1654 that Pascal discussed the questions with the members of the academy but was dissatisfied with their responses (Pascal 1970c: 1137). Instead, on this occasion, he asked one of the members of the group, Pierre de Carcavi, to help him contact Fermat (Bernstein 1996: 61). This is the only occasion when Fermat is known to have discussed mathematics one-to-one with a mathematician other than Mersenne (Singh 1998: 43).

[150] In the text, Pascal enumerates a number of works that he intended to write in various disciplines: number, geometry, the physical sciences, and probability (Pascal 1970b: 1032–35). The first two works proposed eventually appeared as treatises dealing with number properties alongside the *Traité du triangle arithmétique*, though under different names to those mentioned in the text: the *De numericarum potestatum ambitibus* mentioned in the address appears to have given rise to the treatise *Potestatum numericarum summa*, while the *Numeros aliorum multiplices* eventually became the treatise *De numeris multiplicibus* (Mesnard 1970a: 1025–26). There is no explicit mention of the Arithmetic Triangle in the address, suggesting Pascal had not conceived of the main treatise at this stage, probably not writing either version until his correspondence with Fermat, in August (Mesnard 1970a: 1025; Edwards 2003: 42).

autem ac penitus intentatæ materiæ tractatio' [entirely new research dealing with a totally unexplored subject] (Pascal 1970b: 1034). At this stage he was interested in 'matheseos demonstrationes cum aleæ incertitudine jungendo' [joining together mathematical demonstrations and the uncertainty of chance] (Pascal 1970b: 1035). He seemed particularly concerned to find a mathematical solution to what he calls in the address, in French, '*les partis des jeux*' [i.e. the problem of points] (Pascal 1970b: 1034).[151] It is clear that, at the time the address was written, Pascal was 'complete[ly] aware [...] of the practical as well as of the fundamental importance of this new doctrine, the calculus of probabilities' (Rényi 1972: 3).

It is likely that the other works mentioned in the address were never written, as Pascal finished working on probability during the autumn of 1654 and barely returned to it (Edwards 2003: 43). He underwent his second conversion at this time and spent most of the rest of his life at the Abbey at Port-Royal, involved in religious matters and only occasionally concerned with mathematics or science (Edwards 2003: 43). As will be explored in detail in section 5.2.2 below, he had copies of the *Traité du triangle arithmétique, avec quelques autres petits traités* printed in 1654 but they were not sold or distributed until 1665, three years after his death, by his printer (Edwards 2013: 174). By the time the correspondence with Fermat was published in Fermat's posthumous collected works, the results they had discovered had been published by Christiaan Huygens (Daston 1980: 236). In addition, later in the seventeenth century, Newton discovered the binomial theorem for fractional and negative indices and Leibniz and Newton discovered calculus. Both discoveries were based on Wallis's use of the properties of the Arithmetic Triangle in his *Arithmetica infinitorum* [The Arithmetic of Infinitesimals], published in 1656, only two years after Pascal wrote the treatises on the same subject (Edwards 1987: 87).[152]

The failure to publish either the correspondence or the *Traité du triangle arithmétique, avec quelques autres petits traités* meant that Pascal's work with Fermat in solving the problem of points and his work on the Arithmetic Triangle

[151] In full in the text, Pascal says: 'quod gallico nostro idiomate dicitur *faire les partis des jeux*' [what in French is called *faire les partis des jeux*] (Pascal 1970b: 1034).
[152] Wallis is reported to have been informed about the *Traité du triangle arithmétique* soon after it was published in 1665 (Barker 1970: 160), but this would have been after his own work on the Arithmetic Triangle was published.

initially went largely unnoticed outside his close circle of mathematical associates. In the case of the Arithmetic Triangle, this also seems to have been attributable to perceptions of a lack of originality and importance in the work (Taton 1964b: iv). Nevertheless, once the collection of treatises was published, there is evidence that copies found their way to scholars in England (Barker 1970: 160) and it is likely they were read elsewhere.[153] The Latin treatises would have presented no linguistic problems to English scholars, as they were written in the *lingua franca* of the Republic of Letters. In addition, as noted in section 2.1.1, by the time copies of the French treatises, including the *Traité du triangle arithmétique*, were being read across Europe, French had become the second language of the upper echelons of European society (Rickard 1974: 120), from which many scholars came. Boyle, for example, wrote many letters in French, as well as in Latin (Hunter 2001: 28). Moreover, Leibniz wrote in French as well as in Latin and German, while Huygens wrote his works in Latin, French and Dutch (Hofmann 1981: 166; Bos 1981: 612). French was not universally known, however: Oldenburg had to act as intermediary, in French, between Adrien Auzout (1622–1691) and Robert Hooke (1635–1703), neither of whom knew the other's language (Jardine 2006: 253–54).

The perceived lack of originality in the *Traité du triangle arithmétique, avec quelques autres petits traités* came from the fact that both the Arithmetic Triangle and the mathematics within the collection's treatises were well known. The first recorded use of the Arithmetic Triangle dates back to the early eleventh century and it appeared in a number of arithmetic and algebraic works in different forms in the hundred years before Pascal wrote his treatises, including in works by Stifel, Tartaglia and Stevin (Bosmans 1906: 66–71; Katz 2014: 370). In addition, the three key overlapping mathematical elements in the Arithmetic Triangle — the figurate numbers, the numbers from calculating combinations, and the binomial coefficients — had been elaborated well before the seventeenth century (Pengelley 2009: 185).[154] Mesnard believes that

[153] Evidence from the HPB database of research library holdings shows fourteen extant copies, twelve of which are in France or Belgium and two in Germany. All four books with known provenance belonged to French people, such as Jean-Gabriel Petit de Montempuis the rector and Cartesian professor of philosophy at the Sorbonne, and French institutions, including the Séminaire des missions étrangères [Paris Foreign Missions Society], founded in 1663, just before distribution of the *Traité du triangle arithmétique, avec quelques autres petits traités*. This limited information suggests that the audience was mainly found in France.

[154] The figurate numbers were known to the Pythagoreans: they were the successive number sequences in the diagonals of the Arithmetic Triangle (the integers 1, 2, 3, 4, ...; the triangular numbers 1, 3, 6, 10, ...;

Pascal was probably unaware of his predecessors' work, as he seemed to be conscious of little current mathematical research outside his immediate circle (1970b: 1172). It is certainly true that all of the mathematics in the treatises on the Arithmetic Triangle, with the exception of the *Usage pour les partis*, would already have been known to everyone in Mersenne's academy, including Pascal, at least fifteen years before Pascal wrote the *Traité du triangle arithmétique*, from the work on combinatorics published by Mersenne and Hérigone in the *Harmonie universelle* and *Harmonicorum libri* (1636–37), and the *Cursus mathematicus* and *Cours mathématique* (1634–42) respectively, as explored in chapters 3 and 4 above. In addition, Mesnard believes the work on combinations was also prompted by de Gaignières, a friend of Pascal's as well as one of Mersenne's correspondents (1970b: 1172).[155] That is not to say that there is nothing original in the treatises on the Arithmetic Triangle, however: in Shea's opinion, none of Pascal's predecessors 'saw the full implications of their discovery' (2003: 241, note 1). As Edwards notes, Pascal's originality lay in taking all of this knowledge and synthesising it into a single treatise (1987: 57–58). In addition, he possibly produced 'the first complete enunciation and justification [...] of the logical principle of mathematical induction' in the treatises (Pengelley 2009: 195).[156]

Because of his synthesis of the different elements of the Arithmetic Triangle, it is now generally known in western mathematics as Pascal's

---

the tetrahedral numbers 1, 4, 10, 20, ...; and further sequences of figurate numbers in higher dimensions). However, they were not published in tabular form until 1544 when Stifel drew up an extended figurate version of the Arithmetic Triangle in connection with the extraction of algebraic roots (Edwards 1987: 5). Knowledge of combinations dates back to Indian mathematics in the third century BCE but did not appear in recognisable tabulated form in Europe until the sixteenth century when Tartaglia generated the table as part of his analysis of dice games (Edwards 1987: 37; 2013: 169). Similarly, knowledge of binomial expansions — the coefficients in the expansion of $(a+b)^n$ — dates to the twelfth century in both Chinese and Persian mathematics (Merzbach and Boyer 2010: 219; Katz 2014: 214). The Arithmetic Triangle was first created to show the coefficients as early as 1303, by Chinese mathematician Chu Shih-chieh (Zu Shijie, *fl.* 1280–1303), drawing on earlier Chinese sources (Merzbach and Boyer 2010: 183).

[155] In the *Combinationes*, Pascal credits de Gaignières with discovering a practical rule relating to combinations (1665e: 33). De Gaignières had previously corresponded with Mersenne on the subject of combinations, as noted in chapter 4 (De Gaignières 1960: 190–99).

[156] Both the *Traité du triangle arithmétique* and the *Triangulus arithmeticus* include the same example of proof by induction: in *Consect. 11* of the *Triangulus arithmeticus* and *Consequence douziesme* of the *Traité du triangle arithmétique* (Pascal, 1654b: vi; 1665b: 7). As Edwards notes, the priorities for discovery of the method 'have been much debated' (1987: 85). There is general agreement that, although no one mathematician can be said to have specifically invented the process of mathematical induction, it was implicit in the works of many mathematicians from Euclid onwards, until a fully explicit formulation finally emerged either with Maurolico, or with Pascal (Bussey 1917: 200; Ernest 1982: 120–21; Hara 1962: 287). Whether Maurolico or Pascal was the originator of the method of complete induction, it is likely that Pascal encountered induction in Maurolico's work (Edwards 1987: 85, note 13). He is known to have been familiar with Maurolico, referring to his work in the Dettonville letter addressed to Carcavi, so it is possible that he saw the implicit use of induction in his predecessor's work before introducing his own explicit formulation (Pascal 1992e: 430).

Triangle, a name first used in France in the eighteenth century. In 1708, in the introduction to his *Essai d’analyse sur les jeux de hazard* [Essay Analysing Games of Chance], Pierre Rémond de Montmort (1678–1719) described the Arithmetic Triangle as the ‘Table de M. Pascal pour les combinaisons’ [Mr Pascal’s table for combinations] and wrote that he believed Pascal to be its originator (Edwards 1987: x, 71). Similarly, Abraham de Moivre (1667–1754) described the Arithmetic Triangle as the *Triangulum arithmeticum PASCALIANUM* in his *Miscellanea analytica* [Analytical Miscellany] (1730) (Edwards 1987: x). The Arithmetic Triangle’s origins in a number of different mathematical traditions means that the attribution to Pascal is not universally recognised: according to Anne Rooney ‘[i]n Iran, it is called Khayyam’s triangle and in China Yang Hui’s triangle’ (2013: 128). Furthermore, although Edwards believes that Pascal’s contribution means there can be no dispute that ‘the Arithmetic Triangle should bear Pascal’s name’ (1987: ix), many western scholars tend to agree with doubts about the name, including Morris Kline (1972: 272–73), Bosmans (1906: 65–71; 1924: 21–25) and Boyer, the latter of whom refers to the name as ‘largely an accident of history’ (1950: 389).

While the Arithmetic Triangle and the treatises describing it are clearly important within the history of mathematics, they are also important within the study of self-translation. As mentioned above, when the *Traité du triangle arithmétique* finally appeared in 1665, it was published as part of a combined French and Latin collection of treatises. However, a single Latin version of the main treatise, entitled the *Triangulus arithmeticus*, was later discovered amongst the papers belonging to Pascal’s heirs. The distinctness of this version from the *Traité du triangle arithmétique* has only relatively recently been appreciated (Mesnard 1970b: 1168–69, 1173). Close study has shown that this Latin version was the first version of the work, which Pascal then rewrote in French for publication in the second collection of treatises (Mesnard 1964b: 36; Descotes 2001b: 39–40; 2008: 241–42). A second Latin treatise, the *Numeri figurati*, was found with the *Triangulus arithmeticus*; it too was rewritten for the second collection of treatises. Mesnard has established the most complete account of the likely genesis of both collections of treatises. Hara and Descotes have added to his work by clarifying how the two collections correspond to each other.

5.2.2 The collections of treatises on the Arithmetic Triangle

Mesnard has established a likely full history for the creation, printing and publication of the collections of treatises. The outcome of his research is a timeline based on a range of sources, particularly the original printed collections. He was able to examine the collections in detail, including the paper on which they were printed, the typefaces in which they were set, and the ways in which they were compiled. This work was complemented by further sources, including Pascal's correspondence with Fermat, previous editions of Pascal's works, and Hara's earlier research into the treatises. Mesnard's conclusions are important not just in establishing how the two collections of treatises were created, but in determining the extent to which the second, mixed French and Latin collection can be considered a self-translation. If some parts of the second collection were rewritten in French by Pascal but others remained in Latin, does this make the whole collection a self-translation? What are the implications of the presence of new French-only treatises in the second collection? I will answer these questions once I have provided a full account of the known facts, Mesnard's conjectures, and other scholars' comments on those conjectures.

The collection of mixed French and Latin treatises was published under the title *Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere* by Guillaume Desprez (*c*. 1629–1708) in 1665 (Mesnard 1964b: 33).[157] The sheet following the title page has an *Avertissement* [Notice] on the back, written by Desprez, which begins:

> Ces Traittez n'ont point encore paru, quoy qu'il y ayt desia long temps qu'ils soient composez. On les a trouvez tous Imprimez parmy les papiers de Monsieur Pascal, ce qui fait voir qu'il avoit eu dessein de les publier. Mais ayant, peu de temps apres, entierement quitté ces sortes déstudes, il negligea de faire paroistre ces Ouvrages, que l'on a jugé à propos de donner au public apres sa mort, pour ne le pas priver de l'avantage qu'il en pourra retirer
>
> [These Treatises have not yet appeared, even though they were typeset a long time ago. They were found already printed among Mr Pascal's

[157] The collection consists of what Mesnard calls 'quatre éléments distincts' [four distinct parts] (1970b: 1167). As the four parts were printed as a single collection, and have always been treated as such, I will continue to do so throughout this chapter. However, the pagination for each part begins at page 1; consequently, for reference purposes, I have split the collection into its constituent parts in the bibliography. Further information about the composition of the collections of treatises on the Arithmetic Triangle can be found in appendix 6. The spelling in the title given here is that of the original publication.

papers, which shows that he had intended to have them published. However, having shortly afterwards abandoned this sort of work completely, he neglected to have these Works published. It was deemed appropriate to issue them after his death so that the public would no longer be denied the benefit that they may gain from them] (Pascal 1665a: iii).

From the wording of the *Avertissement*, it seems likely that the mixed French and Latin collection was printed at the time it was written, in 1654, before Pascal's second conversion and the temporary abandonment of mathematics mentioned by Desprez, but not published until 1665, when Desprez added the title page, the *Avertissement*, a contents page and a diagram of the Arithmetic Triangle (Mesnard 1964b: 34; 1970b: 1166). Desprez states that the printed copies were found amongst Pascal's possessions when he died.[158] They were almost certainly passed to him by Pascal's heirs, his sister Gilberte and her family, to sort through, as the family is known to have done the same with Pascal's writings on the cycloid. It is not known whether Pascal's heirs specifically asked Desprez to add the *Avertissement* and contents page or whether he undertook to do so on his own initiative (Mesnard 1964b: 34–35). The treatises on the Arithmetic Triangle would probably not have been made available to the public in 1665 without Desprez's intervention.

A different set of printed treatises was later found amongst collections deriving from the Périer family papers that can now be found at the *Bibliothèque municipale* in Clermont-Ferrand. This version contains both collections of treatises, 'recueilli tel quel par les Périer' [collected together as found by the Périer family], but none of the additional introductory pages printed by Desprez (Mesnard 1964b: 36). This dual set of treatises seems to have been kept separately, probably by Pascal himself, and retained in the family after his death (Mesnard 1964b: 36; 1970b: 1168). Pascal seems to have disposed of all other copies of this full set of treatises (Mesnard 1970b: 1169). Although previous scholars noted its existence, they missed its significance, not appreciating the importance of the two Latin treatises that had hitherto only been known in their published French versions: the *Triangulus arithmeticus* and *Numeri figurati* (Mesnard 1964b: 35). The publication history of the treatises on the Arithmetic

[158] Although it is not known how many copies Pascal originally had printed, Mesnard cites Martin's finding that Desprez still had 200 copies in his shop in 1673 (Martin 1950: 219) (Mesnard 1964b: 37, note 1). Mesnard also believes that Desprez is unlikely to have been the original printer (1964b: 34).

Triangle suggests that it was not until the early twentieth century that an understanding of the importance of these Latin treatises first emerged. It was Mesnard who first concluded that Pascal initially wrote a collection of treatises on the Arithmetic Triangle in Latin and then compiled a second collection that included new versions of some of the original treatises and some new treatises in French only, while leaving the remaining Latin treatises untouched (1970b: 1166–69).[159] The outcomes of his research have subsequently been tabulated by both Hara (1981a: 35–36) and Descotes (2001b: 40; 2008: 242) to show how the two collections of treatises correspond to each other. A summary of the work of all three scholars is shown in figure 11 below.[160]

In Mesnard's view, two of the smaller, Latin-only treatises, the *De numeris multiplicibus* and the *Potestatum numericarum summa*, were almost certainly written and printed first, as they have different typefaces to the rest of the treatises and do not mention the Arithmetic Triangle at all (Mesnard 1970b: 1170). He believes that they were either finished or close to completion when Pascal addressed the Parisian Academy, in spring 1654, and that Pascal probably then worked on the figurate numbers, leading him to the Arithmetic Triangle.[161] Having discovered (or rediscovered) the Arithmetic Triangle, Pascal was able to pick out the properties relating to both the figurate numbers and

---

[159] Mesnard provides an account of the means by which Pascal's works have come down to us, including the collection containing the *Triangulus arithmeticus* (1964b). Although he does not give a precise date for scholars' recognition of the Latin treatise as an early version of the *Traité du triangle arithmétique*, his research meant that his was the first edition to consider the existence of two separate versions (1964b: 36, note 1). By his own estimation, Mesnard's was the ninth edition of the *Œuvres complètes* [Complete Works] (eight when he wrote the introduction and a ninth by the time it went to print) (1964a: 7). The first two editions, Bossut's complete works of 1799 and the 1858 edition, printed by Charles Lahure and largely based on Bossut's edition, were both incomplete, and both used the published bilingual text from 1665 in its entirety, with no mention of the Latin versions of the translated texts. The first major edition to contain all of Pascal's known works was published between 1908 and 1921 and edited by Brunschvicg, Pierre Boutroux and Félix Gazier. They published the *De numeris multiplicibus* and the *Potestatum numericarum summa* separately, having established that they were written before the other treatises, and left the rest in the order of the 1665 version (Mesnard 1970b: 1173). They discovered the *Triangulus arithmeticus* and the *Numeri figurati* very late in the day and so added the previously unpublished texts as an appendix, but without establishing that they were parts of a separate version. The next three editions of the *Œuvres complètes*, edited by Fortunat Strowski (1929–31), Henri Massis (1926–27) and Jean Hytier (1928–29) were all largely based on the edition produced by Brunschvicg et al and so added nothing new to scholarship surrounding the origins of the texts. The two later editions, edited by Jacques Chevalier (1954) and Louis Lafuma (1963) ignored the Latin-only texts that did not appear in the mixed-language collection, simply reprinting the 1665 edition (Mesnard 1964a: 7, 1970b: 1173).

[160] The table has been constructed to show the different sections as numbered on the contents page of the published collection (parts I–XI) and the way they correspond to the sections in the original, unpublished collection. A fuller version of the part of the table showing the mixed collection can be found in appendix 6, with full details of treatise titles, paratext and pagination.

[161] Edwards disagrees with Mesnard on the date of the address, believing that it probably took place in July rather than in the spring, as Mesnard suggests (1987: 86, note 16). This disagreement has no material impact on the relationship between the two collections of treatises and the status of the second collection as a self-translation of the first.

Latin collection	**French and Latin collection**	
Triangulus arithmeticus	*I*	*Traité du triangle arithmétique*
Numeri figurati[162] *Combinationes*[163]	*II*	*Divers usages* *Usage pour les ordres numériques* *Usage pour les combinaisons*
	III	*Usage pour les partis*
	IV	*Usage pour les binômes et apotomes*
Numeri figurati	*V*	*Traité des ordres numériques*
	VI	*De numericis ordinibus*
De numerorum continuorum	*VII*	*De numerorum continuorum*
Numericarum potestatum	*VIII*	*Numericarum potestatum*
Combinationes	*IX*	*Combinationes*
Potestatum numericarum summa	*X*	*Potestatum numericarum summa*
De numeris multiplicibus	*XI*	*De numeris multiplicibus*

Figure 11: The correspondence between the two collections of treatises

combinations to which his work on the *problème des partis* had been leading him (Mesnard 1970b: 1170). Hara's research into the development of the technique of mathematical induction showed that the technique was fully developed in the *Triangulus mathematicus,* but not at the time Pascal wrote to Fermat on 29 July 1654 (1962: 292–95). Mesnard concluded that it is therefore likely that the *Triangulus mathematicus* and the rest of the Latin treatises were not completed and printed until after this date (1970b: 1170–71).

Pascal then reworked the *Triangulus arithmeticus,* parts of the *Numeri figurati* and the beginning of *Combinationes* in French, and put them together with two new treatises showing how the Arithmetic Triangle could be applied, particularly to solve the *problème des partis*. The new and reworked treatises were then printed and combined with the remaining Latin treatises to create the mixed collection of treatises in the form in which it finally appeared in 1665 (Mesnard 1970b: 1171). Mesnard has established that the *Traité du triangle arithmétique* was almost certainly only printed just before Pascal sent a copy to Fermat on 29 August 1654, meaning that less than a month separates the composition and printing of the two versions of the principal treatise in the two collections (1970b: 1171).

[162] Most of the *Numeri figurati* was reworked for the second collection, but the work was split into three components: the opening 'definitions' section takes up most of the *Usage pour les ordres numériques*, the propositions in the middle of the work were translated as the *Traité des ordres numériques*, and the problems at the end were largely left intact as the *De numericis ordinibus*.

[163] Approximately the first third of this treatise was reworked for the second collection as the *Usage pour les combinaisons*, while the whole of the Latin text was also retained.

What does Mesnard's reconstruction of the writing and printing of the two collections of treatises tell us about the relationship between them? Mesnard's own view is that some of the Latin texts in the first collection were 'profondément remaniées' [extensively redrafted] (1970b: 1170). As a consequence, he concludes that '[c]es deux impressions, si proches qu'elles aient été dans le temps, forment chacune un ensemble complet' [close together as they were written in time, these two printed works both form complete collections] (Mesnard 1970b: 1173).[164] This is an important statement when considering the status of the two collections as self-translations. It gives rise to a number of questions. First, do the collections as we think of them represent what Pascal himself intended for them? Are the two collections truly separate? What are the implications for the status of the collections as self-translations? And what does this mean for the bilingual treatises within the collections? Answering the first three questions will enable me to approach the fourth question more clearly, particularly as it relates to the principal treatises in the collections.

Clearly, as figure 11 shows, there is a considerable amount of overlap between the two collections. Pascal wrote the first, Latin collection for two audiences: the scholarly French audience to whom he addressed his *Celeberrimæ matheseos academiæ Parisiensi* and a Latin-reading European audience. Moreover, there is evidence he found it easier to discuss aspects of the Arithmetic Triangle in Latin: dealing with combinations in one of his letters to Fermat, he stated that 'je vous le dirai en latin, car le français n'y vaut rien' [I will tell you about it in Latin, as French is of no use here] (Pascal 1970c: 1140). Hara believes that Pascal may have intended to rewrite the entire first collection in French in order to be able to present his work to a larger audience but was unable to do so when, as noted above, he temporarily abandoned mathematical work following his second conversion (1981a: 40). This would imply that the second collection does not represent Pascal's final intention for his work, and that it cannot truly be considered a fully separate collection. However, Hara does not present any compelling evidence for his suggestion. More convincing is Descotes's contention that Pascal chose to translate into French only those parts of the original collection that show the link between the Arithmetic Triangle

[164] Mesnard's distinction is between two 'impressions'; I follow him in this distinction between two separate 'printed works' that produced separate collections of treatises.

and its applications: the principal treatise and the applications to figurate numbers and combinations (1988: 255; 2001b: 43). Descotes believes Pascal did this to appeal to an audience that was different to the one for whom he had written the original Latin treatises (2001b: 43). This view is supported by Pascal's decision to compose new treatises solely in French with further useful applications to complement the translated treatises. In particular, the *Usage pour les partis* was a treatise with a very practical purpose that was most likely to be read by people with an interest in games of chance and not necessarily solely in pure mathematics (Descotes 2001a: 60; 2001b: 42). As Descotes points out, Pascal could also have composed this treatise in Latin if he had wished, as he had shown in the address to the Parisian Academy that he possessed the Latin vocabulary to do so (2001b: 42). Descotes argues convincingly that those treatises that were left in Latin were those that did not relate directly to the Arithmetic Triangle, dealing with the more theoretical aspects of figurate numbers and combinations (2001b: 42). These treatises would only have been of interest to the Latin-reading specialists (Descotes 2001a: 59). Moreover, recent research by Descotes has shown that many of the Latin treatises were revised specifically for the second collection, implying that they were meant to remain in Latin (2020: 162). Descotes believes that ,while some of the revisions, such as corrections to spellings, punctuation and page headers and changes to the alignment of lines of text, could be attributed to Desprez, the printer of the second collection, other changes, including corrections and additions to mathematical text, can only have been carried out by Pascal himself (2020: 162–71). The only other possibility is that the changes were carried out by a collaborating mathematician, following Pascal's instructions. However, as noted by Singh above, there is no indication that Pascal discussed any of his work on probability with anyone other than Fermat. The implication of Descotes's reasoning is that Pascal identified different audiences for the two collections of his work. The first collection was written solely with Latin-reading scholars in mind, while the second edition was written and edited both for that audience and for interested French-readers. In reality, of course, some readers both in France and across Europe would have been capable of reading all of the treatises, in both languages, while others would have been restricted to treatises in one of the languages. Nevertheless, Pascal's differing intentions in creating the two collections mean that they should be considered as separate, each existing in its own right as a distinct version of the treatises on the Arithmetic Triangle.

As the collections can be considered as separate complete collections of treatises compiled in the manner Pascal intended, they can therefore be considered as an instance of self-translation. This conclusion is supported by close examination of the process for creating the second collections. Descotes believes, like Mesnard, that the second collection should be treated as a rewriting of the first collection. He characterises what he calls the 'transformation' of the first collection into the second collection as 'une *explication*, un développement et une amplification de sa structure logique' [an *explanation*, a development and an amplification of its logical structure] into a quite different collection (2001b: 68). According to Descotes, this is not the first time that Pascal refashioned his writing: he rewrote a number of his works as soon as he completed the original version, as if finishing them gave him fresh ideas to incorporate.[165] This was, however, the only occasion on which he truly 'transformed' a work by rewriting it after it was printed (2008: 242–43).

What did the 'transformation' of the first collection entail? The rewriting process operated at a number of levels: changes in structure (splitting the *Numeri figurati* into three separate texts, for example), the addition of new texts (the *Usage pour les partis* and the *Usage pour les binômes et apotomes*), full and partial translation of texts (the *Triangulus arithmeticus*, the *Numeri figurati* and the *Combinationes*), and the decision to leave a number of Latin texts in their original form, including part of the *Numeri figurati* and the original version of the *Combinationes*. Clearly, the addition of new texts and the existence of untranslated treatises means that the second collection should be considered a *partial* self-translation. The collections were composed as partially bilingual versions of a work on the subject of the Arithmetic Triangle almost simultaneously in summer 1654 by a single identifiable individual and involved a degree of rewriting, as specified in the composite definition of self-translation derived in chapter 1.

[165] Pascal rewrote the religious works the *Écrits sur la grâce* [Writings on Grace], the *Lettre sur la possibilité des commandements* [Letter on the Possibility of the Commandments] and the *Traité de la prédestination* [Treatise on Predestination]. The difference in the case of the treatises on the Arithmetic Triangle is that they were reworked after printing, whereas the former works were refashioned before printing and publication.

The conclusion that the second collection is a partial self-translation of the first collection means that one focus for self-translation research in this instance should be on the individual bilingual treatises as separate self-translated works within the collections. The separation of the rewriting process into a range of levels above makes it clear that, even within the collections of treatises on the Arithmetic Triangle, Pascal's self-translation practice was not uniform. This picture of Pascal's practice is further broadened by examination of his other self-translated works — the letter and reports on the competition involving the cycloid. Close study of the reports reveals that Pascal did not rewrite and restructure them in the way he did with the treatises on the Arithmetic Triangle, but largely retained their content, terminology and structure (Pascal 1992a, 1992b, 1992c, 1992d), resulting in a faithful translation. This view of Pascal's bilingual writing is supported by Mesnard's approach to translation of Latin texts: while he provides French translations of the Latin treatises on the Arithmetic Triangle, he comments about the reports on the cycloid competition that 'la correspondance entre l'une et l'autre [version] est assez rigoureuse pour dispenser d'une traduction mot à mot' [the close way in which they (the versions) match means that a word-for-word translation is not required] (1992a: 149).

Does the conclusion that the Latin and French versions of the reports on the cycloid competition are faithful translations mean that they alone can be considered as self-translations? The composite definition in chapter 1 makes it clear that self-translation can apply to a range of translation practices, including literal and faithful translations and extensive rewriting. Using this definition, different conclusions would undoubtedly be reached in each of the three self-translations in the *Traité du triangle arithmétique, avec quelques autres petits traités*: the partial translation of the *Combinationes*, the splitting into three components and translation of two of the parts of the *Numeri figurati*, and the translation of the *Triangulus arithmeticus*.

The rest of this chapter will deal with the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* alone. Very little meaningful research has been conducted into the relationship between the two texts. Descotes is the only scholar to treat Pascal's composition of the *Traité du triangle arithmétique* on the basis of the *Triangulus arithmeticus* as an example of self-translation, stating that ‘Pascal s'y traduit lui-même’ [in it, Pascal self-translates] (2001b: 39). He is the first to note that, although Pascal was involved in translating throughout his life, translating religious texts for his literary and philosophical work, the translation of the *Triangulus arithmeticus* was the first time he translated his own work (2001b: 39).[166] Descotes is also alone in examining the differences between the texts in any real depth at the linguistic, mathematical and rhetorical levels. Hara provides a useful comparison of the propositions, or consequences, in the two texts but, in general, he considers the *Traité du triangle arithmétique* to be little more than a French version of the *Triangulus arithmeticus* with ‘quelques modifications de détail’ [a few changes of detail] (1981a: 37). By comparing the structures of the treatises in greater detail than Hara and by comparing Pascal’s application of his rhetorical method to the texts of the treatises, I aim to determine whether Pascal’s continued development of the Arithmetic Triangle after completing the *Triangulus arithmeticus* means that the *Traité du triangle arithmétique* is more than simply a faithful translation of the Latin original with minor changes, as Hara believes, or whether it stands on its own as a second original, as suggested by Mesnard and Descotes.

5.3 The *Triangulus arithmeticus* and *Traité du triangle arithmétique*: structural comparisons

5.3.1 The overall structures of the two treatises

Both the *Triangulus arithmeticus*, containing ten pages, and the *Traité du triangle arithmétique*, comprising eleven, are short treatises. This is deliberate: Pascal states on numerous occasions in the two collections that he could have included more propositions and examples in the texts. In the *Triangulus arithmeticus*, for example, he says that ‘[m]ultas alias propositiones dare potuissem, sed necessarias solummodo exposui’ [I could have provided a lot of other propositions, but I have only stated the most necessary ones] (1654b: ix). This statement is not used in the *Traité du triangle arithmétique*. Instead, it is moved to the brief introduction to applications of the Arithmetic Triangle known as the *Divers usages*, where Pascal states that ‘j’en laisse [d’usages] bien plus

[166] Pascal translated extracts from ‘la Bible pour l’Apologie, saint Augustin pour les *Écrits sur la Grâce,* de nombreux passages des casuistes pour les *Provinciales*’ [the Bible for the Apology, St Augustine for the *Writings on Grace*, numerous passages by the casuists for the *Provinciales*] (Descotes 2001b: 39). He restricted himself to parts of religious and philosophical works that were useful to him and does not seem to have set out to translate complete works by other writers for publication as translations on any subject (see Philippe Sellier, 1995, for examples of translations of religious passages).

que je n'en donne; c'est une chose estrange combien il [le triangle arithmétique] est fertile en proprietez' [I leave out more (uses) than I give; it is strange how fertile it (the Arithmetic Triangle) is in properties] (1665c: 1).[167] The brevity of the treatises makes them unlike many mathematical works of the period.[168] As well as being brief, they do not contain a dedication or a preface, again unlike many mathematical works of the period.[169] No dedication was needed, as Pascal paid for the printing of all of the treatises in the collection himself, as he did for all of the works printed in his lifetime, as noted in section 5.1 above, and so had no patron to thank and praise (Descotes 2008: 240). Pascal also did not feel the need, as he had in the dedication to Pierre Séguier (1588–1672), the Chancellor of France, that accompanied his mechanical calculator at its presentation in 1645, to seek the support and protection of a highly placed patron or to praise his own efforts and advertise his work (1970a). Descotes further suggests that Pascal could very easily have used a preface to locate the treatises within the history of research into number theory, and remark upon the usefulness of combinations and his new uses of the Arithmetic Triangle (2008: 240). The fact that he chose not to do so may be attributable to contemporary attitudes to mathematics, particularly works on number theory: speculation on the nature of numbers had gained a reputation for being time-consuming, tedious, and unproductive (Descotes 2008: 259). Instead of taking the risk that the treatises would be seen in this light, Pascal chose not to present them in a preface as research on complex number theory, but instead launched straight

[167] Further examples can be found in the 'monitum' in the *Numeri figurati*, where Pascal states that 'Possunt infinita alia dari circa has propositiones' [An infinite number of other remarks may be made about these propositions] (1654a: 6), in the *Usage pour les binômes et apotomes*, where he says that 'Je ne donne point la demonstration de tout cela, parce que d'autres en ont déja traitté' [I will not demonstrate all of this, as others have already done so] (1665d: 16), and in the *Numericarum potestatum*, where he states that 'Horum demonstrationem, paratam quidem, sed prolixam etsi facilem, ac magis tædiosam quam utilem supprimimus, ad illa, quæ plus afferunt fructus quam laboris, vergentes' [The demonstration of these results is ready, but long, though easy, and more tedious than useful: we have left it out, turning instead to research that is more likely to bear fruit than hardship] (1665e: 21).

[168] The list in appendix 1, section C, which provides a sample of sixty mathematical works written before and after Pascal wrote the treatises on the Arithmetic Triangle (i.e. between 1610 and 1665), shows that there was a great deal of variation in the lengths of mathematical works at this time. The works range in length from twenty pages at the shortest (Leurechon's *Discours sur les observations de la comete de 1618*) to over three thousand pages in six volumes for the longest (Hérigone's *Cursus*). Twenty-one of the works (approximately a third) contain fewer than a hundred pages, but thirteen contain more than four hundred. All sixty works sampled are longer than either the *Triangulus arithmeticus* or the *Traité du triangle arithmétique*. It should be noted, however, that seventeen of the works (just over a quarter) are shorter than Pascal's published second collection of treatises, which covers a total of eighty-three pages.

[169] Appendix 1, section C shows that over two-thirds (forty-four) of the mathematical works sampled contain at least one dedication. A similar number contain at least one preface or prolegomenon and, although not all works with dedications also contain prefaces, in the majority of cases the works contain both (thirty-six). Of the ten works that contain neither dedication nor preface, three are under forty pages in length. Only two of the works with no dedication or preface (both by Gassendi) could not be classified as short works. This implies that, while it might be possible for an author to bear the costs of publishing a shorter work, both a patron and a dedication to that patron were required for longer works.

into the Arithmetic Triangle itself (Descotes 2008: 240). It is also possible, as noted above, that Pascal was not fully aware of the mathematical tradition in which he was working and so felt no need to position his work within it.

The *Traité du triangle arithmétique* is directly preceded in its collection by a diagram of the Arithmetic Triangle, represented in a fold-out sheet. The diagram follows the title page, Desprez's notice and the contents page for the whole 1665 published collection, and is separated from them by a blank page. This separation from the paratext indicates that the diagram was added at this point in the work primarily to support the discussion of the physical layout and properties of the Arithmetic Triangle in the *Traité du triangle arithmétique*, and also to support the later treatises, particularly the applications of the Arithmetic Triangle. As will be discussed in section 5.3.2 below, the diagram found with the text of the *Triangulus arithmeticus* was not exactly the same as the one printed with the *Traité du triangle arithmétique* and, unlike in the *Traité du triangle arithmétique*, was not placed in a specific position to indicate its intended function. Mesnard believes it was created at a later date by one of Pascal's heirs and that Pascal's original drawing of the Arithmetic Triangle must be assumed to have been lost (1970b: 1170).

In both treatises, the main text immediately follows the title, which opens the Latin treatise and follows the diagram of the Arithmetic Triangle in the French version. Pascal's discussion of the properties of the Arithmetic Triangle in both the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* is organised into two broad sections: the treatises both begin with a section containing definitions of terms that will be used in the body of the text.[170] In both treatises, this opening definitions section is followed by the treatise proper, where the most important properties of the Arithmetic Triangle are revealed. The main body of the text in both treatises is divided into two sections, although this division is not explicitly marked: first Pascal demonstrates properties relating to the quantities in the individual cells of the Arithmetic Triangle before going on to prove a number of relationships between the quantities in the cells.

[170] This is given the title 'Definitiones' in the Latin treatise and 'Definitions' in the French treatise. Throughout this chapter, I will refer to each one separately by its given name and will refer to them jointly as the definitions sections.

In both versions of the treatise, the definitions section takes up slightly less than two pages. A full discussion of this section and its relevance to the treatises and to Pascal's method can be found in section 5.4.1 below. Pascal's treatment of the Arithmetic Triangle's properties takes up the rest of the treatises: approximately eight pages in the *Triangulus arithmeticus* and nine in the *Traité du triangle arithmétique*. Mesnard has shown that the same typefaces were used in both texts, so the additional page in the French version of the treatise represents an additional page of mathematical material (Mesnard 1970b: 1169). The reasons for this difference in length arise from differences in the internal structure of the main parts of the treatises caused by a mathematical change involving the generator of the Arithmetic Triangle that took place between the writing of the Latin treatise and the French treatise, as described below in section 5.3.3.

After the 'Definitiones' section, the *Triangulus arithmeticus* is made up of eighteen propositions (each one known as a 'consectarium', usually abbreviated to consect.), which account for the majority of the main text, interspersed with two notices (each one known as a 'monitum') to explicate aspects of the propositions, another definition (a 'definitio'), a corollary (a 'corollarium') and, at the end of the treatise, a question to be solved by the reader (a 'problema'). The structure of the main part of the *Traité du triangle arithmétique*, while very similar, is different in a number of ways. The French treatise is made up of nineteen propositions (each one known as a 'consequence') that make up the main content of the treatise, along with eight notices ('advertissements') and, like the *Triangulus arithmeticus*, another definition and a question at the end of the treatise (a 'probleme').[171] There are no corollaries in the *Traité du triangle arithmétique*.[172] The division of the treatise into standard sections reflected Pascal's philosophy of mathematical writing: in the Dettonville letter addressed

[171] From this point onwards, I will refer to the 'Consectaria' and 'Consequences' jointly as 'consequences', and separately using the names given to them by Pascal in the treatises, e.g. *Consect. 11* in the *Triangulus arithmeticus* and *Consequence douziesme* in the *Traité du triangle arithmétique*. In the *Triangulus arithmeticus*, the first ten consequences deal with properties of the triangle, while the final eight deal with proportional relationships between different cells and groups of cells. In the *Traité du triangle arithmétique*, the final eight consequences again deal with proportional relationships between different cells and groups of cells, while the first eleven deal with properties of the triangle.

[172] Most of the treatises in the two collections are made up of similar components, which were standard in sixteenth- and seventeenth-century mathematical texts, as noted in chapter 2. In the Latin collection, the *Numeri figurati*, for example, is made up of a definitions section, eight propositions, one of which is a problem, a notice (after proposition 8), four more problems, the first of which has two corollaries, and a conclusion. In the mixed-language collection, the French treatise *Usage pour les partis* is made up of an introduction, two corollaries, seven 'cases', a lemma, a separate section containing four proposition-problems, one of which contains a corollary, and a conclusion.

to Carcavi in 1658, he wrote that he viewed ‘le style géométrique’ [geometrical, or mathematical, style] as ‘propositions, corollaires, avertissements, etc.’ (1992e: 415). Furthermore, as will be shown below, in both the *Triangulus arithmeticus* and the *Traité du triangle arithmétique*, Pascal incorporated the geometric style of his age into his own methodology and adapted it to his own requirements, providing clear definitions of new terminology in Latin and French, proposing a number of carefully stated ‘consequences’ as theorems, and providing logically coherent ‘demonstrations’ as proofs.[173]

The outline provided above shows that there is a significant degree of similarity between the structures of the two versions of the principal treatise found in the two collections of treatises on the Arithmetic Triangle: they both begin with a definitions section, which is followed by a similar numbers of consequences, a range of notices, a further definition, and a problem to be solved, all based on the diagram of the Arithmetic Triangle. The description also suggests that there are significant differences between the treatises and that these differences relate to two factors in particular: first, the diagrams of the Arithmetic Triangle and, second and most importantly, the change to the generator of the Arithmetic Triangle. The rest of this section will explore these two factors in detail and will highlight their impact on the changes that Pascal made when he reworked the *Triangulus arithmeticus* into the *Traité du triangle arithmétique*.

5.3.2 The diagram of the Arithmetic Triangle

As well as following historical precedent in his use of definitions of terms, propositions, notices and corollaries, as noted above, Pascal will also have seen in the works of Euclid, Mersenne, Hérigone and other mathematicians the practice of adding useful tables and diagrams to the text. Bosmans believes that he took this practice even further, and that his diagram of the Arithmetic Triangle, shown in figure 12 below, was simply the latest version of a diagram that had evolved at the hands of various mathematicians from the mid-sixteenth century onwards (1906: 66–71). Certainly, the origins of Pascal’s diagram can be seen in diagrams printed in a number of pre-seventeenth century texts, as

[173] It should be noted that the words ‘demonstration’ and ‘proof’ are treated as synonymous throughout this chapter. ‘Demonstration’ is the word that seventeenth-century mathematicians generally used to discuss proofs, as can be seen in most mathematical works of the time, including the three selected as case studies for this thesis (see, for example, Serjeantson 2006: 139, 143).

well as in the *Cursus* and both the *Liber de cantibus* and the *Livre des chants*.[174]

The presence of a diagram of the Arithmetic Triangle in the *Triangulus arithmeticus* and *Traité du triangle arithmétique* makes understanding the text easier than without it. This must certainly have been in Pascal's mind when he drew it for the Latin treatise and in Desprez's mind when he chose to produce a printed version to add to the French treatise. The history of the diagram of the Arithmetic Triangle is not wholly clear, though Mesnard believes that it was originally drawn by Pascal for the *Triangulus arithmeticus* in 1654, and was then used, with added French text, to create the engraving used in the French edition of 1665 before subsequently being lost (1970b: 1169–70).[175]

Although a copy of the diagram was found with the copy of the *Triangulus arithmeticus*, it was a later hand-drawn version, almost certainly copied by a member of Pascal's family from the Arithmetic Triangle printed by Desprez in 1665 (Mesnard 1964b: 36; 1970b: 1169–70). Consequently, it is impossible to say definitively whether the diagram was meant to accompany the *Triangulus arithmeticus* as well as the *Traité du triangle arithmétique*, or was simply used by Pascal as a guide while writing the Latin treatise. It would, however, be surprising if Pascal had not intended it to be printed with the *Triangulus arithmeticus*. It should nevertheless be noted that, although the diagram of the Arithmetic Triangle may only have been printed with the French treatise, it represents the case where the generator, G, is equal to 1, which is the subject matter of the Latin treatise and only part of the subject matter of the French treatise, as will be discussed in section 5.3.3 below. This implies that Pascal had his own hand-drawn version of the diagram close by when he was writing the *Triangulus arithmeticus*, as well as when he was composing the *Traité du triangle arithmétique*. Furthermore, a number of the diagram's features are mentioned in the Latin text, including some that are only referred to there and not in the French treatise, suggesting that Mesnard's conclusion noted

[174] As can be seen in appendix 2, part A, Pascal's diagram shows similarities to those drawn up in the 1630s by Hérigone and Mersenne. As noted above, Pascal knew Hérigone when he was younger and was familiar with the *Cursus*, and was introduced to Mersenne's mathematical group by his father.

[175] By the seventeenth century, almost all illustrations, including diagrams like the representation of the Arithmetic Triangle, were made using the technique of engraving on a metal plate, usually copper (Duportal 1914: 73). It is likely that the diagram was produced as a single-sheet print with image and text combined in an etching or engraving (Goldstein 2012: 16–18). In general, up to a thousand copies of an illustration could be made from single-sheet etchings or engravings on copper plates and were run off in smaller numbers, as required by demand (Goldstein 2012: 30).

above regarding the original date of the diagram's composition is correct, and that Pascal intended a version of the diagram to accompany the Latin treatise.

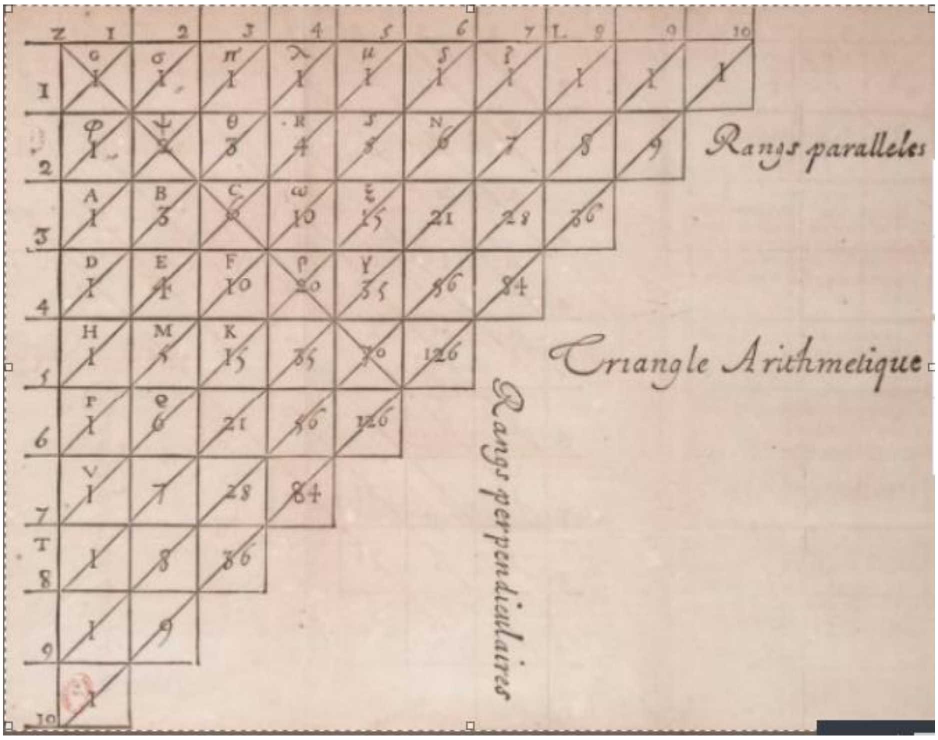


Figure 12: The diagram of the Arithmetic Triangle

It is interesting to note that, although Pascal refers constantly to the Arithmetic Triangle and its properties in both the Latin and the French treatises, and refers throughout both treatises to the cells in the diagram, he does not once actually refer explicitly to the diagram itself. It is not clear why Pascal did not make the link between the diagram and the text explicit in the treatises; it may have been that he felt that his references to its properties and cells were sufficient to make it clear that he was referring to the diagram as the template for all Arithmetic Triangles. If this is so, it is as much the case for the Latin treatise as it is for the French version.

Although the published diagram was probably originally created for the Latin version of the treatise, it is also likely, though not certain, that the labelling of the diagram occurred at a later stage, as it is in French. As can be seen in figure 12, the diagram of the Arithmetic Triangle is entitled simply 'Triangle Arithmetique'. It consists of an array of squares in the shape of a right-angled isosceles triangle, with the right angle positioned in the top left corner. The right angle is labelled Z, and two points, one each along the vertical and horizontal edges of the Arithmetic Triangle, are called T and L respectively. These labels are mentioned in the Latin treatise and so must already have been present when it was written (Z is mentioned on multiple occasions on the first page of the *Triangulus arithmeticus*, for example, but none of the letters are mentioned in the *Traité du triangle arithmétique*). The horizontal rows, numbered from 1 to 10 on the left edge of the Arithmetic Triangle, are labelled 'Rangs paralleles' [Parallel rows] and the vertical columns, also numbered from 1 to 10, along the top of the Arithmetic Triangle, are called 'Rangs perpendiculaires' [Perpendicular rows]. These labels are in French only and so were probably added for printing of the French treatise, as discussed above. It should be noted that, although the numbering of both the rows and the columns ends at 10, Pascal is clearly aware that the Arithmetic Triangle was theoretically infinite, as he says in the *Triangulus arithmeticus* that there are 'infinitæ bases' [an infinity of bases] (1654b: vi) of internal triangles, and therefore an infinity of smaller triangles, within the larger Arithmetic Triangle.

Each square, or cell, in the drawing of the Arithmetic Triangle contains a number. As becomes clear in the treatises, the numbers are placed in the cells based on mathematical rules originating from the cell labelled G, the generator of the Arithmetic Triangle, which is equal to 1 alone in the Latin treatise, but can equal any natural number in the French treatise. The impact of the generalisation of the generator on the French treatise will be dealt with in section 5.3.3 below. Most of the cells also contain a letter: all of the cells up to the seventh 'base', as Pascal calls the left-to-right rising diagonals in the Arithmetic Triangle, contain either an upper-case Roman or lower-case Greek letter. There does not seem to be any organising principle for the letters in the cells. For example, in order from left to right, the six cells in the top row following G contain the Greek letters σ, π, λ, μ, δ, and ζ, while the first six cells in the second row contain a mixture of Greek and Roman letters in the order φ, ψ, θ, R, S, and N. Neither set of letters, Greek or Roman, follows any discernible order in any row or column in the diagram.[176] Some cells do contain clusters of letters that follow each other in the Roman alphabet, such as the array at the beginning of rows 3 and 4 containing the letters A–F inclusive.

[176] The twenty-four lower-case letters of the Greek alphabet, in their standard order, established before Pascal was writing, are: α, β, γ, δ, ε, ζ, η, θ, ι, κ, λ, μ, ν, ξ, ο, π, ρ, σ/ς, τ, υ, φ, χ, ψ, and ω (Horrocks 2010: xviii-xix).

Overall, only twelve of the twenty-four letters in the Greek alphabet are used and only twenty from the seventeenth-century Roman alphabet.[177]

The insertion of the diagram of the Arithmetic Triangle before the main text in the *Traité du triangle arithmétique* undoubtedly has the impact of making the text of the treatise easier to understand, as the reader is able to use the diagram to clarify the propositions in the treatise. It may be that Pascal also intended the diagram to be available to the readers of the Latin treatise for the same purpose. However, the lack of clarity regarding Pascal's intentions in this matter makes it difficult to conclude definitively whether this represents a significant difference between the structure of the two treatises and Pascal's treatment of his different readerships. It also makes it difficult fully to gauge the contribution of the diagram of the Arithmetic Triangle to an assessment of the French treatise's status as a self-translation of the Latin treatise. The conclusions will be clearer once the other significant structural difference between the two treatises, the change to the generator of the Arithmetic Triangle, is taken into account.

5.3.3 The change to the generator of the Arithmetic Triangle

It is clear from the outline in section 5.3.1 above that the main reasons for the additional page of text in the French version of the treatise arise from the addition of a proposition and a number of notices. The addition of these extra sections is the direct consequence of a significant mathematical change: Pascal's altered understanding of the nature of the generator of the numbers in the Arithmetic Triangle and its implications for the way in which the numbers in the cells of the Arithmetic Triangle are generated. It is this change following completion of the *Triangulus arithmeticus* that is the source of Mesnard's description of a 'remaniement' [reworking] of the treatise to create the French text, as noted in section 5.2.2 (1970b: 1169–70).

[177] I and O were almost certainly omitted because of their similarity to the numbers 1 and 0. Members of the letter pairs I/J and U/V were used interchangeably in the treatises, so the absence of I would explain the lack of J and the use of V the absence of U. There is no obvious reason for the omission of X, and there appears to be no clear rationale for the choice of the twelve Greek letters used from the full set of twenty-four. This usage of letters simply as labels differs in some ways from modern mathematical practice. Upper-case Roman letters are still often used to label vertices and intersections of lines on geometrical shapes, generally starting with A and continuing in alphabetical order. Greek letters, both lower-case and upper-case, are generally used to represent quantities in specific situations: the Greek letter θ, for example, is used to signify the size of a general or unknown angle.

The question of generating the numbers in the Arithmetic Triangle is dealt with at the end of the definitions section, but in different ways in the two treatises. The differences between the two texts begin with presentation of the generating process: the title of the subsection dealing with this subject in the *Triangulus arithmeticus* — '*Generatio Numerorum Cellularum Trianguli'* [*Generating Numbers in the Cells in the Triangle*] (1654b: ii) — is subsumed into the text of the *Traité du triangle arithmétique* as '*[o]r les nombres qui se mettent dans chaque cellule se trouvent par cettte* [sic] *methode'* [*Now, the numbers that are placed in each cell can be found using this method*] (1665b: 2).[178]

The text that follows these introductory statements differs from one text to the other because of the change to the generator. In the *Triangulus mathematicus*, Pascal gives specific rules for placing numbers in each of the first four rows, based on the figurate numbers, the number sequences found in the rows: the numbers in the cells in the first row are all 1, while the numbers in the cells in the subsequent rows belong to the series of natural numbers (second row), triangular numbers (third row) and pyramid numbers (fourth row).[179] Pascal is clearly aware that each of these number sequences can be obtained by adding the terms in the previous sequence.[180] He therefore goes on to generalise the pattern to the other rows, stating that the number in any given cell can be obtained from the sum of the numbers in the row above the cell, up to and including the cell above the cell in question (1654b: ii).[181] However, these sequences may only be generated when the generator is 1, as in the *Triangulus arithmeticus*, but not when the generator can take any arbitrary natural number,

---

[178] As noted in the 'Definitions and editorial principles' section at the beginning of the thesis, italicised text in both treatises will be quoted in italics throughout this analysis to present an accurate picture of the *mise-en-page* of the text.
[179] In the *Numeri figurati*, Pascal tells the reader that 'natural numbers', 'triangular numbers' and 'pyramid numbers' are the popular or common names for the sequences; for example, '*Secundum ordinem numericum* voco, seriem eorum qui vulgo naturales dicuntur' [I name the *second order of numbers* the sequence popularly known as the natural numbers] (1654a: 3).
[180] For example, the terms in the sequence of triangle numbers (1, 3, 6, 10, 15, etc.) are generated by adding successive terms in the sequence of natural numbers (i.e. 1, 1 + 2, 1 + 2 + 3, 1 + 2 + 3 + 4, etc.). The same method is used to generate the sequence of pyramid numbers from the triangle numbers (i.e. 1, 1 + 3 = 4, 1 + 3 + 6 = 10, 1 + 3 + 6 + 10 = 20, etc.), and so on for successive sequences, all of which can be found in successive rows and columns of the Arithmetic Triangle. The diagram of the Arithmetic Triangle in figure 12 makes this and other examples in the footnotes clearer.
[181] So, for example, the value of the term in cell K in row 5, column 3 can be deduced by adding the values of all of the cells in row 4 (the row above row 5), up to and including the cell in column 3 (above cell K): the value of cell K is therefore 1 + 4 + 10 = 15.

as in the *Traité du triangle arithmétique*. The change to the generator in the French text leads to changes to the values in the rest of the cells.[182]

Pascal deals with this problem by changing the method for generating the numbers in the cells of the Arithmetic Triangle in the *Traité du triangle arithmétique*. The numbers in the cells are no longer members of sequences of figurate numbers; instead, they now depend directly on the number in cell G, the generating cell: '*Le nombre de la premiere cellule qui est à l'angle droit est arbitraire; mais celuy-là estant placé tous les autres sont forcez*' [*The (choice of the) number in the first cell located at the right angle is arbitrary; but once it is set in place, all of the others are constrained*] (1665b: 2). Pascal provides a universal rule for all triangles with any generator: the number in each cell is the sum of the number in the cells immediately preceding it in both its row and its column (1665b: 2).[183] It is possible that Pascal did not realise when he wrote the Latin treatise that this would also have been true for the case when G is equal to 1.[184]

It is interesting to note, however, that, although Pascal introduces the concept of the arbitrarily chosen generator in the *Traité du triangle arithmétique*, all of the examples in the French treatise come from the same iteration of the Arithmetic Triangle as the examples in the *Triangulus arithmeticus*: the Arithmetic Triangle in the diagram, where the generator is equal to 1. Pascal clearly realised that this was the case: once he has explained how the cells are generated in both treatises, he goes on to state that a number of consequences (i.e. propositions) can therefore be drawn (1654b: ii; 1665b: 2). This is followed in the French treatise by a statement whose equivalent does not appear in the Latin treatise: '*En voicy les principales, ou je considere les triangles, dont le generateur est l'unité; mais ce qui s'en dira conviendra à tous les autres*' [*These are the main ones* (i.e. consequences)*, where I consider triangles whose*

---

[182] So, if, for example, the generator were 2, the number in each cell would double and the value of cell K would be 30. Each number sequence would also be doubled.
[183] For example, the value of cell Y (35) can be found by adding the value in the cell in the preceding row (i.e. ξ = 15) to the value in the cell in the preceding column (ρ = 20).
[184] It is not only the translation from the *Triangulus arithmeticus* to the *Traité du triangle arithmétique* that is affected in this way by the change to the generator. Figurate numbers are the subject of the *Numeri figurati*, yet Pascal never refers to the figurate numbers in the *Traité des ordres numériques,* which is otherwise a reasonably faithful translation of the Latin treatise's propositions, but which deals with 'number sequences' instead of 'figurate numbers'. Pascal adds text to the French treatise by way of greater explanation for his French audience. For example, a number of propositions and corollaries in the Latin text begin with 'Omnis numerus figuratus' [Every figurate number] (1654a: 4–8). In the *Traité des ordres numériques*, this is translated as 'Un nombre de quelque ordre que ce soit' [A number in any sequence whatsoever] (1665e: 1–5).

generator is unity (i.e. 1)*; however, what will be stated will work for all of the others*] (1665b: 2).[185]

It may not be possible to decide definitively why Pascal chose to continue to include examples in his French treatise where the generator was equal to 1, but it is clear, from close study of the text, that his evolving understanding of the universal nature of the generator had implications for both the structure and content of the treatises. The major structural change is a result of the addition of a new first consequence in the *Traité du triangle arithmétique* to introduce the new method for generating the numbers in the cells using the arbitrary generator: it states that all of the numbers in the first row and column of the Arithmetic Triangle must be the same as the generator as they are the sum of the numbers above them in the preceding row and column, whichever of the potentially infinite values the generator takes. In their location at the top and extreme left of the Arithmetic Triangle, these cells either have no cells above them (top row) or to the left of them (first column) and must therefore be the same as the cell that precedes them. It should be noted that this is also true for the case when the generator is equal to 1, but it would have seemed trivial to state this for a single, obvious case in the Latin treatise.

The outcome of adding the new consequence at this stage of the work is a mismatch between the consequences throughout the two treatises: the first consequence in the *Triangulus mathematicus* corresponds to the second consequence in the *Traité du triangle arithmétique*, the second consequence in the *Triangulus mathematicus* to the third consequence in the *Traité du triangle arithmétique,* and so on.[186] It is unclear whether the addition of the first consequence had as much impact as Pascal perhaps intended, however: his

---

[185] Pascal continues to refer to the original Arithmetic Triangle alone in the *Usages*, saying in the introductory *Divers usages*: 'dans toute la suite, je n'entends parler que des Triangles Arithmetiques dont le generateur est l'unité' [in all of what follows I only intend to use Arithmetic Triangles with a generator of one] (1665c: 1). It is possible that Pascal had written the French version of the treatise and had begun the *Usages* before the idea of the arbitrary generator came to him and simply added this statement to the end of the 'definitions' section. It is also possible that he continued to use examples from the *Triangulus arithmeticus*, where the generator was equal to 1, because he realised this was the most important and most familiar of all possible Arithmetic Triangles, and that what was true for this one could be generalised to all of the infinite number of potential Arithmetic Triangles.

[186] This causes a problem in the second collection. In the first collection, both the *Numeri figurati* and *Combinationes* contain references to the consequences in the *Triangulus arithmeticus*. When part of the *Numeri figurati* was translated into the *Usage pour les ordres numériques* for the second collection, the references were changed to align with the consequences in the *Traité du triangle arithmétique*. The same did not happen for the *Combinationes*. Descotes believes that Pascal stopped revising the Latin treatises in the second collection before he reached the *Combinationes*, leaving the second collection unfinished (2020: 174–77).

continued use of examples in the *Traité du triangle arithmétique* where the generator is equal to 1, linked to the appearance of the Arithmetic Triangle with the same generator in the diagram preceding the text, means that the reader of the French treatise is likely to have perceived the Arithmetic Triangle in much the same way as the reader of the Latin text. The only real difference would have been in their understanding of how the values in the cells are generated, as noted above.

The impact of the arbitrary choice of the generator is more likely to have been appreciated as a result of the addition of a number of notices at various points throughout the French treatise. The function of these notices is to explain that a consequence is true for all possible values of G, and not just when G is 1. So, for example, the fourth consequence in the French treatise is followed by a statement explaining how the statement of the consequence could have been generalised: '*J'ay dit dans l'enonciation [...]; mais si c'estoit un autre nombre, il faudroit dire [...]'* [*I stated in the enunciation (...); but if it* (i.e. the generator) *were another number, I should have stated (...)*] (1665b: 4). Similar notices are placed after the eighth and ninth consequences respectively: '*Si le generateur n'estoit pas l'unité*' [*If the generator were not unity* (i.e., 1)] (1665b: 5) and '*Si le generateur estoit autre que l'unité*' [*If the generator were anything other than unity*] (1665b: 6). Clearly, these notices were not present in the *Triangulus arithmeticus*, as the notion of the arbitrary generator had not yet occurred to Pascal.

Not only does Pascal create additional sections (a consequence and a number of notices) in the French treatise as a result of generalisation of the generator, but he also inserts additional text and explanations throughout the *Traité du triangle arithmétique* to remind the reader of the implications of using the arbitrary generator. This includes repeating statements in the text to reinforce the general nature of the Arithmetic Triangle and changing some of the demonstrations in the consequences to reflect this generality. For example, each of the nineteen consequences in the *Traité du triangle arithmétique* begins with 'En tout Triangle Arithmétique' [In every Arithmetic Triangle] (1665b: 2–10). The arbitrary nature of the generator in the *Traité du triangle arithmétique* means that each of its consequences refers to all possible cases of the Arithmetic Triangle. This statement only appears in three of the consequences in the *Triangulus arithmeticus* — *Consect. 14*, *Consect. 15* and *Consect. 17* — which all begin with 'In omni triangulo arithmetico' [In every Arithmetic Triangle] (1654b: vii–viii). The meaning of 'every triangle' has now changed: where, in the Latin treatise, it referred simply to any triangle within the Arithmetic Triangle that contains the generator of 1, now, in the French treatise, it also encompasses any Arithmetic Triangle generated by any arbitrarily chosen generator. The impact of the repetition of the statement 'En tout Triangle Arithmétique' is to reinforce the universality of the consequences in the French treatise in comparison with the Latin treatise.[187]

As well as adding the new general formula 'En tout Triangle Arithmétique', Pascal also changes the wording of the demonstrations in two of the consequences (the third and fourth) in the *Triangulus arithmeticus* for use in the *Traité du triangle arithmétique* (fourth and fifth consequences). In both cases, unity, or 1, the original generator, is replaced by G, the universal arbitrary generator. So, for example, 'in tertia æquantur, A, π; unitates enim sunt' [in the third (base), A and π are equal; as they are unity] (1654b: iii) in *Consect. 4* in the Latin treatise is changed to '[d]ans la troisiesme A, ψ, π, il est visible de mesme que les reciproques π, A, sont égales entr'elles et à G' [in the third (base), Aψπ, it is also clear that the reciprocals π and A are equal to each other, and to G] (1665b: 4) for *Consequence cinquiesme* in the French version. In this way, the universality of the generator is underlined.

The overall impact of the structural changes to the *Traité du triangle arithmétique* in comparison with the *Triangulus arithmeticus* — the addition of a new first consequence, a number of notices, 'En tout Triangle Arithmétique' to all of the consequences, and the replacement of unity by G in some of the consequences — will undoubtedly have made the reader of the French treatise aware of the impact of the arbitrary generator in a way that the reader of the Latin treatise could not be. However, as stated above, the presence of the diagram of the Arithmetic Triangle with generator equal to 1 and the use of examples with the same generator will have undermined the impact of the additional text. It should be noted, too, that the two treatises are similar in structure despite the changes from the Latin version to the French one. From a self-translation perspective, both the similarity between the structures of the

[187] This is a transformation in meaning that Descotes has also noted (2001b: 48).

treatises and the decision largely to retain the examples with a generator equal to 1 mean that the divergence between the two treatises is not as great as it could have been. The changes caused by the introduction of the arbitrary generator nevertheless demonstrate that the creation of the second version of the treatise was not a simple act of transposing the first version into the second one. Consequently, the French version of the treatise should be considered not simply as a faithful translation, in the sense discussed in sections 1.1 and 2.1.4, but as a new, reworked version of the original in a new language. It will now remain to be seen whether this is still the case once account has been taken of the content of the treatises — the definitions, demonstrations and symbols Pascal uses to highlight the properties of the Arithmetic Triangle.

5.4 Pascal's rhetorical method

Whereas the differences in structure between the Latin and French versions of the treatise suggest that the French version of the treatise was not a faithful translation of the Latin version, Pascal's rhetorical approach is very similar in the two versions of the treatise. As I will show, however, this does not mean that the text of the definitions, consequences, notice and problems in the French version are necessarily faithful translations of the same features in the Latin text.

Little is known about Pascal's own rhetorical education, as he was educated at home by his father (Descotes 1993: 17; Topliss 1966: 10). Despite the lack of research, there is general consensus that Pascal was well versed in the rhetorical tradition of his time (Fumaroli 1979: 362–63; Declercq 1999: 631).[188] In fact, Descotes suggests that Pascal was so steeped in rhetoric that 'l'originalité de Pascal savant en son siècle tient à ce que le souci de la mise en forme rhétorique et littéraire a orienté toute son œuvre' [the originality of Pascal the scholar in his century comes from the fact that the preoccupation with rhetorical and literary forms influenced all of his work] (1988: 251). The writers of the *Logique de Port-Royal* clearly agreed, stating that 'Feu Mr Pascal […] sçavoit autant de veritable Rhetorique, que personne en ait jamais sceu' [The

[188] This is highly likely as, according to Patricia Topliss, 'traditional Rhetoric continued to dominate education in general' in the seventeenth century (1966: 12).

late Mr Pascal (...) knew as much true Rhetoric as anyone has ever known] (Arnauld and Nicole 1664: 341).[189]

As noted in chapter 2, sixteenth- and seventeenth-century mathematical argument was largely based on the model of rigour provided by new editions of Euclid's *Elements*, with which Pascal was known to be familiar (Serfati 2005: 24).[190] Descotes believes that Pascal felt that having his own rhetorical method would mark him out as a true mathematician (a 'véritable géomètre') (1993: 48).[191] Pascal used his experience of writing mathematical treatises to begin developing his own method and, according to Descotes, the same was true for his scientific work:

> [s]es écrits méthodologiques tirent *a posteriori* les conclusions de ses recherches antérieures et dessinent la voie des suivantes: la *Lettre à Le Pailleur* systématise la méthode expérimentale mise en œuvre sur le problème du vide, *L'Esprit géométrique* celle du *Triangle arithmétique*
>
> [his methodological writings draw retrospective conclusions from his earlier research: the *Lettre à Le Pailleur* systematises the experimental method applied in the problem of the vacuum, (*De) l'esprit géométrique* the method applied in the treatises on the Arithmetic Triangle] (1993: 40).

Descotes's comment implies that *De l'esprit géométrique* would provide the ideal vehicle for analysing Pascal's *Triangulus arithmeticus* and *Traité du triangle arithmétique*. Consequently, I will use *De l'esprit géométrique* to support my analysis of Pascal's practice in the principal treatises on the Arithmetic Triangle in sections 5.4.1 and 5.4.2 below, once I have outlined the main ideas contained in its two parts.

De l'esprit géométrique is often considered to be Pascal's presentation of 'an explicit theory of knowledge' (Clarke 2003: 104) or 'his own discourse on the

---

[189] The *Logique de Port-Royal* was the basic source book for the teaching and learning of logic for almost two hundred years, and was still in use in parts of Europe until the late nineteenth century (Adamson 1995: 9). Its authors, Antoine Arnauld (1612–1694) and Pierre Nicole (1625–1695), used some of Pascal's ideas from *De l'esprit géométrique* (Adamson 1995: 54). This includes the concept of 'mots primitifs' [primitive words], which is introduced later in this section, and which Arnauld and Nicole discussed as 'termes primitifs' [primitive terms] (1664: 121).

[190] Pascal's sister Gilberte reported in her *Vie de Monsieur Pascal* that her father gave her brother a copy of the *Elements* to read during his leisure time (1964: 575, 606). It is not known which edition of the *Elements* Pascal read, but it is highly probable that he knew Clavius's Latin translation and commentary, which was the best-known contemporary version (Mesnard 1991a: 376). He would almost certainly have read this work either in the original or in Hérigone's Latin and French versions that took up the whole of the first volume of the *Cursus* (Descotes 1993: 118). Most importantly, the *Elements* provided mathematicians, Pascal included, 'with a model of how "pure mathematics" should be written, with well-thought-out axioms, precise definitions, carefully stated theorems, and logically coherent proofs' (Katz 2014: 51).

[191] Ivo Schneider notes that: 'The French term "géomètre" used by Pascal is the usual expression for a mathematician in the 17th and 18th centuries in France' (2000: 73, note 1).

method' (Khalfa 2003: 131), that outlines and expounds an entirely coherent position primarily focused on finding and stating the truth (Davidson 1965: 111). Thus, the most revealing insights into Pascal's thinking about proof and persuasion in mathematics in general and the treatises on the Arithmetic Triangle in particular come from the two treatises that are often printed together in this single work: *Réflexions sur la géométrie en général* and *De l'art de persuader*.[192] The two works were not published until the eighteenth century, but were used as part of the Port-Royal *Logique* from its first edition in 1662 (Mesnard 1991a: 360). The exact date of composition of both parts of the text is unclear, though there is agreement that they were both written between Pascal's second conversion in 1654 and publication of the first edition of the *Logique*.[193]

Pascal uses *De l'art de persuader* to outline his general views on rhetoric as the art of persuasion, while in *Réflexions sur la géométrie en général* he focuses on the ways in which more specifically mathematical methods can be used to convince an audience of the truth of a mathematical argument. Hugh Davidson sees the two parts of *De l'esprit géométrique* as 'complementary', 'two [...] approaches to the same situation' (1965: 112). The degree of overlap between them means that aspects of both are applicable to analysis of the treatises on the Arithmetic Triangle. In *De l'art de persuader*, Pascal states that he believes that people can be persuaded in one of two ways: convinced either by the use of 'vérités démontrées' [proven truths] that will appeal to their 'entendement' [understanding, or reason], or persuaded by 'l'agrément' [pleasing things] that will appeal to their 'volonté' [will] (1991: 413). He declares,

---

[192] The titles of the individual sections of the treatise and the overall title are subject to variation. They have often been published as separate but linked treatises under the titles *De l'esprit géométrique* and *De l'art de persuader*. Bernard Clerté and Martine Lhoste-Navarre refer to them as *L'Esprit de la géométrie* and *De l'art de persuader*. Mesnard and Descotes see them as two parts of a single treatise, *De l'esprit géométrique,* separately titled *Réflexions sur la géométrie en général* and *De l'art de persuader*. Mesnard notes that this was how it was set out in the text, now lost, that forms the basis of editions of the work, and was how it was viewed by both Nicole and Leibniz. The error in the title can be attributed to the first printer to publish the full text (Mesnard 1991a: 360–61). I will follow Mesnard's and Descotes's practice, with one slight alteration, and refer to the whole treatise as *De l'esprit géométrique*, to the first part simply as *Réflexions sur la géométrie*, for the sake of brevity, and to the second part as *De l'art de persuader*.

[193] Mesnard dates the composition of the complete work to 1655 (1991a: 374). Brunschvicg et al believe that the two parts of the treatise were written 'approximately' in the winter of 1658–59 (1914: 231). Chevalier states that there is general agreement that the work was written either in 1657 or 1658 as a preface to a work called *Essai sur les éléments de géométrie* [Essay on the Elements of Geometry] that Pascal abandoned following a disagreement with Arnauld. More important than the precise date of composition is the fact that there can be little doubt that parts of the treatises go back to Pascal's mathematical thinking from 1654 (Chevalier 1954: 575).

however, that he will only provide rules for convincing readers of the truth and not for appealing to his audience (1991: 416). The reason is straightforward: as he states in the *Réflexions sur la géométrie*, only the first of these options can be turned into a method, ‘la méthode de prouver la vérité’ [the method for proving the truth] (1991: 390). This reflection can be traced back to Euclid’s desire to use demonstrations to convince readers of the truth of theorems (Barbin 1988: 6–7). Nevertheless, as Descotes suggests, while Pascal clearly prefers the ‘art de convaincre’ [art of convincing], he retains ‘le souci de toucher un public plus vaste que celui des savants, et d’employer à cet effet l’art de plaire’ [the desire to reach a larger audience than the scholars and to use the art of pleasing to achieve this] (1993: 40–41). As will be demonstrated below, there are enough differences between Pascal’s deployment of his method between the two versions of the treatise to suggest that, as a minimum, he is aware of the need not to discourage his French audience with overly theoretical writing while trying to convince them of his theories relating to the Arithmetic Triangle.

As Pascal explains in the *Réflexions sur la géométrie*, the appeal to reason can be translated into a method based on geometry, as ‘[l]a géométrie […] a expliqué l’art de découvrir les vérités inconnues’ [geometry (...) has explained the art of uncovering hidden truths] (1991: 390). The geometrical method is ideal because ‘elle seule sait les véritables règles du raisonnement’ [it alone recognises the true rules of reasoning] and ‘est presque la seule des sciences humaines qui en produise d’infaillibles, parce qu’elle seule observe la véritable méthode’ [is almost the only human science that produces infallible (demonstrations), because it alone observes the true method] (1991: 391).

So, what is this true method? In *De l’art de persuader*, Pascal breaks it down into a set of rules, which he summarises as follows in the *Réflexions sur la géométrie*:

> Cette véritable méthode, qui formerait les démonstrations dans la plus haute excellence, s’il était possible d’y arriver, consisterait en deux choses principales: l’une, de n’employer aucun terme dont on n’eût auparavant expliqué nettement le sens; l’autre, de n’avancer jamais aucune proposition qu’on ne démontrât par des vérités déjà connues; c’est-à-dire, en un mot, à définir tous les termes et à prouver toutes les propositions

> [This true method, which would create demonstrations of the highest quality, if that were attainable, would consist of two main elements: first, not to use any term whose meaning has not previously been clearly explained; second, not to put forward any proposition that is not demonstrated using truths that are already known; i.e., in short, to define all terms and prove all propositions] (1991: 393).

Pascal goes on to show in the *Réflexions sur la géométrie* that he is aware that the apparently ideal nature of his method would make it unachievable: if terms can only be based on previously defined terms and propositions on previously known truths, what is the basis for these previously established definitions and propositions? Do the words and concepts used to define and prove them respectively also need to be defined and proved, *ad infinitum*? In order to overcome this potential problem and make his method practicable, Pascal introduces the epistemological concepts of 'primitive words' and 'clear principles' that do not require defining and proving: 'en poussant les recherches de plus en plus, on arrive nécessairement à des mots primitifs qu'on ne peut plus définir, et à des principes si clairs qu'on n'en trouve plus qui le soient davantage pour servir à leur preuve' [in searching further and further, we will inevitably reach a point where we find primitive words that we cannot define and principles that are so clear that we will not be able to find clearer ones to help prove them] (1991: 395). Pascal attributes the lack of need to define primitive words and explain clear principles to what he terms 'la lumière naturelle' [natural light], human intuition that means the words and principles are understood without the need for further explanation (1991: 395).[194] In summary, then, Pascal's method consists in defining terms and demonstrating proofs clearly, using clearly understood first principles and terms that do not require proof or definition.

Opinions on the importance and originality of the approach to rhetoric and the formulation of a mathematical method set out in *De l'esprit géométrique* vary greatly. Coumet describes it as the first real progress with regard to the axiomatic method since Aristotle (1979: 77). Topliss takes the diametrically opposite view: she believes that any claim suggesting that Pascal created a completely new rhetorical theory ignores the fact that Pascal's conception of

---

[194] This is similar to Descartes's own notion of natural light, as set out in the *Meditationes*, whereby truths are perceived so clearly and distinctly in the mind that the will acknowledges them immediately (Boyle 1999: 610).

rhetoric does not differ fundamentally from classical sources (1966: 10). Clearly, Pascal's search for a universal method based on geometry has a lot in common with Descartes's *mathesis universalis*, as expressed in the fourth rule in the *Regulæ ad directionem ingenii* (1998: 97), and with his application of the methods in the *Discours de la méthode* to *La Géométrie*, for example. Moreover, the notion of 'mots primitifs' echoes Aristotle's insistence in the *Topics* on the use of previously defined, intelligible terms in demonstrations (1960: 575 [VI 141a 29–30]) and the idea of first principles that 'do not admit of demonstration' can be found in the *Prior Analytics* (1960: 37 [72b: 11–13]). Other aspects of Pascal's mathematical method can be seen in Aristotle's philosophical works, as will be discussed in the sections that follow.

For the purposes of this thesis, the question of the originality of Pascal's method is less important than the way in which it sheds light on the process of composing the two versions of the treatises on the Arithmetic Triangle, particularly with regard to his use of terminology, especially definitions, and mathematical demonstrations. As he set out in *De l'esprit géométrique*, Pascal's method is clearly geometrical, i.e. mathematical (Davidson 1965: 111). Since the treatise was written in the period after Pascal wrote the treatises on the Arithmetic Triangle and, as noted above, seems clearly to have been based mainly on their composition — he wrote no other mathematical treatises around this period — I will use the two parts of *De l'esprit géométrique* to analyse and elucidate Pascal's use of definitions and demonstrations in the *Triangulus arithmeticus* and the *Traité du triangle arithmétique*, examine the differences between his practice in the two treatises, and draw conclusions about the implications of my findings for the bilingual work. Although I will focus on the principal treatises in the collection, I will also refer to some of the other treatises as appropriate and relevant to the discussion of Pascal's method.

5.4.1 Definitions and terminology

Pascal's focus on the importance of definition in demonstrations recalls aspects of Aristotle's thinking on the subject. In the *Prior Analytics*, Aristotle gives two meanings for 'definition', the less important of which provides 'an account of what a thing is, [...] an explanation of the meaning of the name', i.e. a terminological or nominal definition (1960: 207 [93b 29–32]); more important in his view is definition as ‘a form of words which explain *why* a thing exists’ (1960: 207 [93b 39–40]). He further states that it would be absurd to think of definitions solely as ‘an expression meaning the same as the name’ (1960: 199 [92b 27–29]). By contrast, Pascal’s focus in the *Réflexions sur la géométrie* is solely on nominal definitions. This concentration on nominal definitions was typical of the age: providing names and definitions for new concepts was one of the questions that most exercised scholars in the late sixteenth and early seventeenth centuries (Coumet 1979: 83; Strowski 1913: 70). Clerté concludes that this was a way of both avoiding arguments with scholastic philosophers about definitions that incorporate the essence of an object and of establishing the sciences as subjects where reason should dominate (1986: 73).

Pascal makes his position clear in the *Réflexions sur la géométrie*: ‘On ne reconnaît en géométrie que les seules définitions que les logiciens appellent définitions de nom, c’est-à-dire que les seules impositions de nom aux choses qu’on a clairement désignées en termes parfaitement connus’ [The only definitions recognised in geometry are what logicians call nominal definitions, i.e. only names applied to things that have been clearly described in completely familiar terms] (1991: 393). The purpose of using nominal definitions is straightforward: ‘d’éclaircir et d’abréger le discours en exprimant, par le seul nom qu’on impose, ce qui ne se pourrait dire qu’en plusieurs termes’ [to clarify and shorten discussion by expressing, using only the name imposed, that which could only be indicated using a number of terms] (1991: 393). The term can be chosen at will, but must not relate to more than one object and should have no other meaning than the meaning ascribed to it by its definition (1991: 394).[195] In the ‘indispensable’ rules that he sets out in *De l’art de persuader*, Pascal adds that the terms a mathematician introduces must in no way be obscure or ambiguous and must themselves contain only terms that are already well known (1991: 420). He also states that the mathematician should not define terms that are already well known (1991: 420). In the rest of this section, I will demonstrate how Pascal puts his method into practice in the definitions sections of the treatises and how he uses the notion of previously understood and defined terms in his use of other mathematical terminology.

[195] This would therefore be a rule with which Mersenne’s use of the term ‘corollaire’, as highlighted in section 4.3.4 above, would fail to comply. Mersenne’s lack of precision is exactly what Pascal aimed to avoid with his method.

In line with his method, in the opening section of both versions of the treatise, Pascal provides meanings for the terms given to the parts of the Arithmetic Triangle, for later use in the consequences.[196] There is a large degree of overlap between the terms defined in the two treatises. It should be noted, however, that there are a number of differences in the ways in which Pascal applies his method between the two versions. As will be seen below, Pascal does not define precisely the same terms in the two versions of the treatise, and chooses different terminology for some concepts, altering the way in which he labels the terms between the two versions of the treatise. He also uses similar, but subtly different techniques to make the defined terms stand out, and introduces the majority of defined terms in different ways in the two treatises.

Pascal begins both treatises by naming the Arithmetic Triangle. He then goes on to establish the meanings of the terms allocated to its basic elements, using the externally placed labels on the Arithmetic Triangle (the Z at the right angle, the L by column header 8, and the T by row header 8) in the *Triangulus arithmeticus*, but not in the *Traité du triangle arithmétique*. He deploys the labels in the Latin treatise to denote lines and internal triangles in the Arithmetic Triangle. For example, he begins the description of the Arithmetic Triangle by saying: 'Ex puncto quolibet Z aguntur ZL, ZT, perpendiculares' [From some point Z, the perpendicular lines ZL, ZT are drawn].[197] This description clearly refers to the topmost and leftmost lines in the Arithmetic Triangle. By contrast, in the *Traité du triangle arithmétique* Pascal decides instead to use the cell labels and refer to the top row and first column instead of the lines, stating that '*Je mene d'un point quelconque, G, deux lignes perpendiculaires GV, Gζ*' [*I draw two perpendicular lines, GV, Gζ, from some point, G*]. This change means that the description in the French version of the treatise is less mathematically correct than in the Latin version, as GV and Gζ are not lines like ZL and ZT, but rows in the Arithmetic Triangle.

---

[196] As definitions are part of Pascal's rhetorical method, it is not surprising that he begins a number of the other associated treatises with definitions sections, in both Latin and French: the *Numeri figurati*, the *Combinationes*, the *Potestatum numericarum summa*, the *De numerorum continuorum*, the *Usage pour les ordres numériques* and the *Usage pour les combinaisons*. In the first three named treatises, the sections are given a separate title; this is not the case for the latter three treatises.

[197] For the rest of this section, all references from the definitions sections in the *Triangulus arithmeticus* (1654b: i–ii) and *Traité du triangle mathematique* (1665b: 1–2) will not be cited individually as they are all from the same two pages in each treatise. References from the main part of the treatises will, however, be provided.

The differences in describing the lines in the Arithmetic Triangle result in differences in labelling the triangles within it. In the *Triangulus arithmeticus*, Pascal states that the diagonal line joining the equivalent points at the end of the first division on each side of the triangle '*primum triangulum* 1Z1 constituit, estque ipsa *prima Basis*' [forms the *first triangle* 1Z1, and is itself the *first Base*].[198] The same is then said to be true of the second diagonal line, 2Z2, and is generalised to all other lines. The statement in the *Traité du triangle arithmétique* leaves out the label for the triangle, saying simply: '*En suitte je joins les points de la premiere division qui sont dans chacune des deux lignes, par une autre ligne qui forme un triangle dont elle est* la base' [*I then join the points in the first division that are in each of the two lines using another line that forms a triangle of which it is* the base]. The same method of description is used for the second triangle and to generalise for all triangles. Throughout the process of defining the Arithmetic Triangle — introducing it and labelling the lines and triangles within it — Pascal's language is briefer and more technical in the Latin version than in the French version.

There are fewer differences between the two texts in the most basic terms for elements within the Arithmetic Triangle. The rising diagonals are known as 'bases' of the internal triangles: each one is a 'base' in the French treatise, and a '*basis*', with successive bases known as '*prima Basis*', '*secunda Basis*' [*first Base, second Base*], and so on, in the Latin treatise. The individual squares in the Arithmetic Triangle are defined as '*Cellulæ*' and 'Cellules' [Cells] in the Latin and French texts respectively, so that the cells located in the same base are known simply as '*cellulæ eiusdem basis*' or 'cellules d'une mesme base'. Cells in the same base that are the same distance from the end of the base are termed 'reciprocals': '*reciprocæ*' or 'reciproques'.

Having named the fundamental elements of the Arithmetic Triangle — its cells, its internal triangles, and the bases of the internal triangles — Pascal then goes on to provide definitions for the rows and columns in the triangles. The terminology and definitions in the French treatise are generally more straightforward than in the Latin treatise. Again, this might have been a consequence of Pascal's awareness of a different audience for the second treatise, but it could equally have been because he had time to reflect on and

[198] Note that 'estque' is printed as 'est que' in the text.

replace any awkward terminology from the Latin treatise. In the latter case, the decision to update terminology for the French version of the treatise would mirror the introduction of mathematical improvements in the form of the universal generator. Each row in the Latin treatise is known as a '*series*', with successive rows known as the '*prima series*' [*first row*], '*secunda series*' [*second row*], and so on, but there is no term provided for the columns. Pascal, does, however, provide Latin terms for the headers of both the rows and columns — '*exponentes serierum*' [*row exponents*] and '*radices*' [*roots*] respectively — which then allows him to describe the cells that can be found in the same row or column as each other as '*ejusdem seriei*' [*in the same row*] and '*corradicales*' [*co-radicals*], without needing a separate term for 'column'.[199] Pascal seems initially to have considered the column headers (but not the row headers) to be the roots of the terms in the individual cells, similar in mathematical nature to square roots, cube roots and so on. By the time he wrote the French treatise, he had created terminology for the columns that dispensed with the mathematical notion of roots and more closely approximated the terminology used to describe the rows. Each row and column in the French treatise is a 'rang parallele' [parallel row] or a 'rang perpendiculaire' [perpendicular row], while cells located in the same row or column are 'cellules d'un mesme rang parallele' [cells in the same row] or 'cellules d'un mesme rang perpendiculaire' [cells in the same column] respectively, and the row and column headers are both simply known as 'les exposans' [the exponents].[200] Gone are notions of roots and co-radicality that may have confused non-expert readers of the French text, replaced with more straightforward terminology that treats the rows and columns as similar entities.

The changes Pascal makes to his definitions as he develops his ideas for the French text are also reflected in the manner in which he explains them, frequently using different cells, and therefore different values. For example, different rows and columns in the Latin and French versions of the treatise are used to illustrate cells in the same row, column and base, and to illustrate reciprocal cells. In the Latin treatise Pascal states that 'Cellulæ igitur v.g. C, ω,

[199] Pascal also uses the terms 'radices' [roots] and 'exponentes' [exponents] for column and row headers in the *Numeri figurati* (1654a: 4, 5, 7, 8, 10, 11).
[200] In the *Usage pour les ordres numériques* (1654c: 2–3) Pascal does, however, use the term 'racines' [roots] and 'exposants' [exponents] of the number sequences found in the Arithmetic Triangle, just as he uses the terms 'radices' and 'exponentes' in the *Numeri figurati* 1654a: 3–4).

sunt *ejusdem seriei*' [Therefore cells such as C and ω are in the *same row*], whereas in the French version he uses the example of 'cellules d'un mesme rang parallele, *comme les cellules G, σ, π, etc., ou φ, ψ, θ, etc.*' [cells in the same row, *like cells G, σ, π, etc., or φ, ψ, θ, etc.*] (1665b: 1). This means that the same point is made using the third row of the Arithmetic Triangle in the Latin version of the treatise and the top two rows in the French treatise. The use of three values from each of the top two rows makes the point easier to understand in the French treatise than the brief reference to two values in a single row lower down the Arithmetic Triangle in the *Triangulus mathematicus*.[201]

Pascal defines a final term in the opening section of the *Traité du triangle arithmétique* alone: 'le Generateur *du triangle*' [the Generator *of the triangle*]. This term was added after the *Triangulus mathematicus* was completed to reflect the increased importance of the generator in the French treatise. As discussed above, the concept of generating the terms is not absent from the *Triangulus mathematicus*: there is a subsection at the end of the definitions section in the Latin treatise, entitled '*Generatio Numerorum Cellularum Trianguli'* [*Generating Numbers in the Cells in the Triangle*] devoted to explaining how the terms in the Arithmetic Triangle in the diagram are produced. Pascal does not consider '*Generatio'* to be sufficiently important in the Latin treatise to be denoted as a term and circumscribed more precisely. By the time he wrote the French version, however, he considered the cell generating the numbers in the Arithmetic Triangle in a different light, one more deserving of precise naming and definition.

Pascal introduces another new term in the brief definitions section later in both treatises: '*Cellulas Dividentis*' (1654b: v) or 'Cellules de la Dividente' (1665b: 6) [Cells on the Divident].[202] Pascal designates the 'divident' as the leading, descending diagonal that bisects the right angle at Z and serves as the axis of symmetry for the Arithmetic Triangle. This appears to be a term of Pascal's own invention, based on the cognate Latin present participle 'dividens'

---

[201] The same use of different examples to make the same point can be seen in the consequences: for example, the demonstration of the result in the *Consectarium primum* begins 'Sit quævis cellula, F' [Let there be some cell, F] (1654b: ii), while in the equivalent *Consequence seconde* it begins 'Soit une cellule quelconque *ω*' [Let there be some cell, ω] (1665b: 3).

[202] Savitsky translates this term as 'dividend' (Pascal 1959: 72), while Scofield prefers 'bisector' (Pascal 1952b: 451); I have chosen to use the Latin term 'divident': Pascal created a French neologism, so I have translated with an English one.

[dividing, separating]. The presence of this definition in the middle of the treatise rather than at the beginning with other newly defined terms can be explained by the fact that it is the only new term that is not required early in either text: Pascal does not define it until he needs it for *Consect. 10* and *Consequence onziesme*.

Pascal's determination to show the efficacy of his method for providing nominal definitions is reinforced using a range of techniques throughout the definitions section in both treatises, including use of the active voice in the French treatise and contrasting typefaces in both treatises. There are both similarities and differences in the way that voice is deployed in the two versions of the treatise. In both treatises, elements of the triangles are passively 'named' or 'called' a range of terms. So, for example, cells with the same diagonal base in the Arithmetic Triangle 'are called cells in the same base' ('dicuntur *cellulæ eiusdem basis'* and '*sont dites* cellules d'une mesme base'). In general, use of the passive is far more prevalent in the *Triangulus arithmeticus*: while the Latin version begins '*Triangulus Arithmeticus* sic construitur' [*The Arithmetic Triangle* is constructed as follows], the *Traité du triangle arithmétique* opens with the active '*J'Appelle* Triangle Arithmétique, *une figure dont la construction est telle*' [*I Name a shape constructed as follows* (the) Arithmetic Triangle]. This transposition of the Latin passive into the first-person singular appears throughout the definitions section. Where actions are 'done' to lines and points in the Arithmetic Triangle in the definitions section in the Latin treatise, it is Pascal who carries them out in the French version. Hence, 'Punctum primæ divisionis [...] jungit recta' [The straight line (...) joins the point in the first division] becomes 'En suitte je joints les points de la premiere division' [Then I join the points in the first division] in the French treatise, and 'quadrata, quæ *Cellulæ* vocantur' [squares that are named Cells] becomes '*petits quarrez, que j'appelle* Cellules' [*small squares that I name* Cells]. In the *Traité du triangle arithmétique*, Pascal seems to be directly addressing his French-speaking audience, made up within France largely of interested amateurs, including the members of the salon that he had recently been in the habit of attending. By talking directly to his audience, Pascal sets out to establish his authority as an expert, provide his readers with a sense of the relevance and importance of this work in particular and mathematics in general, and to give them a sense that they are members of a wider mathematical community. Pascal also uses the first-person singular in the *Numeri figurati*, a text that was written at approximately the same time as the *Triangulus arithmeticus*, in this case introducing terms to be defined with ‘voco’ [I name]. This leaves the *Triangulus arithmeticus* as a case apart; as the first treatise written in either language, it is likely that Pascal began by adopting the conventional scientific passive voice with a scholarly audience in mind, before switching to the more authoritative and inclusive first-person active.

While use of the active voice serves a range of purposes in the *Traité du triangle arithmétique*, contrasting typefaces are used to reinforce the importance of the terms and their definitions in both versions of the treatise, though in slightly different ways. In the *Triangulus arithmeticus*, the vast majority of the text — in both the definitions section and the rest of the treatise — is printed in roman type, whereas the terms being defined are in italics. The use of italics in this way conformed to its contemporary use: having been relegated from the mid-sixteenth century onwards to an auxiliary role alongside roman type, it was now being used ‘pour faire ressortir certains mots du texte’ [to make certain words stand out from the text] in exactly the way that Pascal wanted (Laliberté 2004: 12). The practice in the French treatise is similar, but with an added layer of contrast. The main text of the *Traité du triangle arithmétique* is set in roman type but, in this instance, the text of the definitions section is set in italics to contrast with it, while the terms being defined are set in roman type to contrast with the rest of the section. In both texts, the terms being defined stand out from the rest of the text, as Pascal presumably wanted them to do, in order to emphasise their importance to the treatises. In the *Traité du triangle arithmétique* alone, the whole definitions section also stands in contrast to the rest of treatise.[203] It is not clear why Pascal chose different highlighting strategies in the two texts. However, as with the arbitrary generator, it may have been an idea that developed in his mind between writing the two versions of the treatise.

Typefaces are not used to emphasise the other mathematical terminology found in the treatises. Other specialised terms used in the treatises

[203] In each of the other treatises in both collections containing ‘definitions’ sections, the words being defined are set in italics to make them stand out against the rest of the text, as in the *Triangulus arithmeticus*.

fall into two types: terminology relating to the structural elements of the treatises, and a range of commonly understood mathematical terms. Both types of term can be seen as examples of the well-known, instinctively understood mathematical terms that Pascal calls ‘primitive words’, terms, as he states in the *Réflexions sur la géométrie*, that ‘sont tellement éclaircis et définis qu’on n’a pas besoin de dictionnaire pour en entendre aucun. De sorte qu’en un mot tous ces termes sont parfaitement intelligibles, ou par la lumière naturelle, ou par les définitions qu’elle [la géométrie] en donne’ [are so clear and well defined that there is no need for a dictionary to understand any of them. With the result that, in short, these terms are perfectly easy to understand, either by means of natural light or the definitions it (mathematics) provides] (1991: 400).

The majority of both types of terminology — terms describing the structural elements of the treatises and well understood mathematical terms — are common to both treatises, as most pairs of terms in the two treatises are cognates of each other. The majority of the words describing the elements of the treatise — including ‘definitiones’ and ‘definitions’, and ‘lemma’ and ‘lemme’ — were standard by the mid-seventeenth century and are clearly cognates. These terms were widely used in Hérigone’s *Cursus mathematicus* and *Cours mathématique* and in Mersenne’s *Harmonicorum libri* and *Harmonie universelle*, as well as many other contemporary mathematical works. However, the most consistently used terms throughout both treatises — ‘consectarium’ in the Latin treatise, and ‘consequence’ in the French treatise — were not standard. It would have been far more usual to have used the cognates ‘propositiones’ or ‘propositions’, in the same way as Hérigone and Mersenne in the other case-study works, translators of Euclid, and Pascal himself in some of the treatises accompanying the *Triangulus arithmeticus* and the *Traité du triangle arithmétique*, both in Latin and in French.[204] In fact, Pascal occasionally refers to the consequences as propositions in both versions of the treatise. He calls *Consect. 11* and its French equivalent, *Consequence douziesme*, ‘propositions’ within the text of the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* (1654b: vi; 1665b: 7), and says, at the very end of the Latin treatise, that ‘[m]ultas alias propositiones dare potuissem’ [I could have provided a lot of other propositions] (1654b: ix). Most significantly, a number of

[204] Including the *Numeri figurati*, the *De numerorum continuorum*, the *Combinationes*, the *De numeris multiplicibus*, the *Traité des ordres numériques*, and the *Usage pour les combinaisons*.

the propositions in the *Numeri figurati* are the same as the consequences in the *Triangulus mathematicus*, with some key words altered. 'Prop. 5' in the *Numeri figurati* is a typical example: not only is its wording almost identical to that of 'Consect. 5' in the *Triangulus mathematicus*, but Pascal finishes it with the statement '[i]lla nihil aliud est quam consect. 5. triang. arith.' [this is nothing more than consequence 5 in the *Triangulus arithmeticus*] (1654a: 5). In each of the examples above, Pascal shows clearly that he considers 'consequence' and 'proposition' to be synonyms.[205]

The terms 'consectarium' and 'consequence' originate in Aristotle's treatment, in the second chapter of book one of the *Prior Analytics*, of logical consequences as the link between the premises and conclusions in a syllogism (Shapiro 2005b: 654). Hérigone refers to consequences in a similar way in both versions of the preface to the reader in volume one of the *Cursus*, as the elements that link his propositions to their demonstrations, ensuring logical consistency: 'la demonstration s'entretient depuis son commencement jusques à la conclusion, par une suite continuë de consequences legitimes, necessaires' [the demonstration communicates from its beginning to the end using a continuous series of legitimate and necessary consequences] (Hérigone 1634b: xi). Pascal uses the terms in a different sense to both Aristotle and Hérigone: in his case, the consequences describe results that follow logically from the explanations provided in the opening sections of the treatises on how the numbers in the triangle are generated, not the steps involved in the reasoning process. This is clear in both treatises: following his own reasoning, Pascal states 'Unde hæc colligo Consectaria' [Whence I draw the following Consequences] and 'D'où se tirent plusieurs consequences' [Whence a number of consequences are drawn] (1654b: ii; 1665b: 2).[206] Pascal's practice in extending the meaning of 'consequence' in this way therefore stands in contrast to Hérigone's approach in the main text of the *Cursus*, where he complies with standard usage and demonstrates the truth of 'propositions'. The unsettled

[205] A further synonym may be 'theorem' [theorema], as this is how Pascal refers to the first proposition in the *De numerorum continuorum* (1665e: 13).
[206] In her translation of the *Traité du triangle arithmétique*, Savitsky translates 'D'où se tirent plusieurs consequences' as 'From these facts there arise several consequences' (Pascal 1959: 69), but then uses the term *Corollary* for the nineteen *Consequences*, a translation that is clearly inappropriate for my purposes, as the term 'corollarium' is used alongside 'consectarium' in the Latin treatise. Scofield is consistent in his use of *Consequence* in both the translation of 'D'où se tirent plusieurs consequences' (Pascal 1952b: 448) and the nineteen *Consequences* in the French treatise. Because of the clear link to logic in Pascal's words, and because of Hérigone's use of the term, I have chosen to use the English word 'consequence' to describe a 'consectarium' or 'consequence' throughout this chapter.

meaning of the term ‘consectarium’ is reflected in other contemporary mathematicians’ writing: in his work on statics, published in 1584, for example, Stevin uses the term to mean ‘conclusions’ (Duhem 2012: 529, footnote 23), while Viète deploys it to refer to generalised solutions of geometrical relations that gave rise to equations (Dadić 1996: 121).

Most of the rest of the mathematical vocabulary in the *Traité du triangle arithmétique* and the *Triangulus mathematicus* would have been fairly straightforward for anyone with an interest in mathematics.[207] Pascal’s use of bilingual terminology was supported by what Andrew Taylor refers to as the ‘linguistic affinity’ and Claude Buridant as the ‘affinité génétique’ [genetic affinity] between Latin and the Romance vernacular languages, which would have made writing the French treatise on the basis of the Latin version more straightforward than if Pascal had either had to invent a new term or search for a non-cognate equivalent term (Taylor 2014: 339; Buridant 2011: 381).

One pair of cognates in the treatises is the subject of specific discussion in *Réflexions sur la géométrie*: the terms ‘unitas’ and ‘unité’ [unity], which are used in both treatises to represent the number 1. Pascal explains that Euclid and other early mathematicians did not include 1 as a number because to do so would have caused difficulty for some of the number properties they were defining (1991: 408).[208] The debate about the number 1 was one of the liveliest areas of mathematical debate in the early seventeenth century. Pascal’s position is similar to that taken by most of his contemporaries (Mesnard 1991a: 379). He rejects the idea that unity is not a number: ‘cette unité est l’origine de tous les nombres’ [this unity is the source of all the numbers] (1991: 401). Pascal uses both ‘unity’ and the digit 1 in both treatises. He tends to use unity in his definitions and demonstrations, while he uses both ‘unity’ and 1 in

[207] As can be seen in appendix 3, most of the terminology had been well established in Latin and French for a number of centuries. Examples include the following standard vocabulary: ‘triangulus’ and ‘triangle’, ‘arithmeticus’ and ‘arithmétique’, ‘punctus’ and ‘point’, ‘rectus’ and ‘ligne’, ‘basis’ and ‘base’, ‘divisio’ and ‘division’, ‘latus’ and ‘costez’ (side), ‘quadratus’ and ‘quarrez’ (square), ‘summa’ and ‘somme’, ‘dupla’ and ‘double’, ‘multiplicare’ and ‘multiplier’ ‘dividere’ and ‘diviser’, ‘quotiens’ and ‘quotient’, ‘proportio’ and ‘proportion’, ‘ratio’ and ‘raison’, ‘æquatur/æquantur’ and ‘egale/egalent’, ‘numerus’ and ‘nombre’, and ‘moins’, ‘ajouter’, and ‘produit’ that did not appear in the Latin version of the treatise. The words that had entered French more recently, such as ‘parallele’, and ‘perpendiculaire’ (both 16th century), and ‘diagonalement’ (early 17th century), and their Latin equivalents, ‘parallelus’, ‘perpendicularis’ (16th century neo-Latin) and ‘diagonaliter’, would be known to a mathematical audience too.

[208] In the ‘Definitions’ at the beginning of volume VII of the *Elements*, Euclid defines unity as ‘that by virtue of which each of the things that exist is called one’, and a number as ‘a multitude composed of units’ (Euclid 1956, 2: 277). The term is translated into English to reflect both of Euclid’s meanings. Hence ‘unity’ is used as a synonym for the number 1, while ‘unit’ describes the place value of the far right-hand digit in a number (e.g. 324 consists of three hundreds, two tens and four units).

examples. For example, in the definitions section in the Latin treatise, Pascal states that in the top row of the Arithmetic Triangle ‘quævis cellula continent unitatem’ [each cell contains unity], while in the definitions section in the French treatise he only considers triangles ‘dont le generateur est l’unité’ [whose generator is unity]. There is not necessarily strict demarcation between the use of ‘unity’ and 1 in the same examples in the two versions of the treatise. Therefore, for example, in *Consect. 7*, Pascal states that ‘Etenim prima basis ex generatione est 1’ [Since, by generation, the first base is 1] (1654b: iv), while in *Consequence huictiesme* he states that ‘Car la premiere base est l’unité’ [Since the first base is unity] (1665b: 5).

Pascal’s use of terminology differs slightly between the two treatises, but overall there are far more similarities than differences. Most, but not all, of the terms defined in the Latin treatise are also defined in the French treatise and, in both treatises, these terms are set in contrasting type to the rest of the text, albeit in different ways. Where there are differences between the two texts, this may arise from Pascal’s desire to accommodate a less mathematically experienced French audience, or it may simply be that his definitions evolved during the rewriting process. In both versions of the treatise, Pascal follows the rules regarding definitions from his own method, as set out in both parts of *De l’esprit géométrique*. He simply uses ‘définitions de nom’ and ensures that terms identified in the definitions sections of the treatises are given clear meanings and are clearly highlighted. In addition to the new terms he introduces in the treatises, Pascal is also careful to follow his own strictures about using only known terminology that is intelligible and therefore not in need of clarification or definition. In so doing, he generally uses cognates that are available to him, making translation more straightforward.

Pascal’s use of cognate terminology in the two versions of the treatise clearly indicates that the *Traité du triangle arithmétique* should be considered a French version of the *Triangulus arithmeticus*, where Pascal’s thinking has developed, leading him to introduce a small number of changes. In this respect, the *Traité du triangle arithmétique* emerges as a second original version of the treatise on the Arithmetic Triangle rather than a faithful translation of the Latin text. Following this examination of Pascal’s use of terminology in the light of his own methods, and the conclusion that the French treatise can be considered a second original at the terminological level, I will investigate his use of demonstration in a similar manner in the next section.

5.4.2 Demonstration and proof

As set out above, Pascal's rhetorical approach to demonstration and proof, as described in the *Réflexions sur la géométrie*, was to 'prouver toutes les propositions' using previously accepted principles (1991: 393). As with definitions, Pascal introduced a number of rules governing demonstrations in *De l'art de persuader*. Two of the rules are considered indispensable ('règles nécessaires pour les démonstrations'): mathematicians must prove all propositions using only clear axioms and previously proven or agreed propositions, and must ensure that, when doing so, they keep a clear idea in mind of the meaning of the newly defined terms being used (1991: 420–21). A further important rule states that there is no need for mathematicians to prove propositions that have already been proved and agreed (1991: 420).

Pascal's method of proof involves the arrangement of propositions in a logical order, in keeping with the requirements of rhetoric: he talks in *De l'art de persuader* about 'l'ordre dans lequel on doit disposer les propositions, pour être dans une suite excellente et géométrique' [the order in which propositions should be arranged so that they are in an excellent mathematical sequence] (1991: 421). He proposes establishing this as a rule, but does not complete this section of the treatise. Nevertheless, as noted above, it is clear that Pascal deliberately divided the propositions in the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* into two sections, creating a logical structure for the propositions in the two versions of the treatise. Both texts contain a series of propositions setting out properties of the Arithmetic Triangle, mostly using deductive reasoning, though one proposition also contains the first formal example of proof by induction in the history of mathematics. In this section, I will examine Pascal's method for proving propositions and the language he uses to do so, comparing and contrasting them between the two versions of the text.

The expected sequence for setting out the deductive reasoning in a mathematical proposition is provided in Euclid's *Elements* and in the preface to the reader in Hérigone's *Cursus* (1634b: xii), both of which Pascal read, as previously established. Pascal sought to organise his demonstrations in both versions of the treatise by following the structure recommended by Proclus in his commentary on the *Elements*, as described in section 2.2.2: this included the enunciation; the exposition, or setting out; the definition of a goal; the construction, or preparation; the proof, or demonstration; and the conclusion. All of the propositions in the two treatises follow this template, though not all contain every element. Therefore, each proposition begins with a statement, which is referred to in one of the notices in the *Traité du triangle arithmétique*, using Proclus's term, as an '*enonciation*' (1665b: 4). The statements are written in a larger typeface than the rest of the text, presumably to make them stand out and to emphasise their relative importance. They are followed by the rest of the proposition, printed in a smaller typeface, that uses specific examples from the Arithmetic Triangle. This generally begins with an explanation of what is required, followed by mathematical reasoning that leads to, or constructs, a demonstration of how to find what is required. In all cases, the demonstration is completed with a conclusion. Uniquely in the case of the twelfth proposition, the demonstration, which is a proof by induction, is referred to, in text that appears only in the *Traité du triangle arithmétique*, as 'cette preuve' [this proof] (1665b: 8), rather than 'cette demonstration'.

All of the demonstrations in the treatises follow a similar linguistic structure to accompany their logical structure. Following enunciation of the consequence, they follow a version of the pattern: 'Sit (or Sint) ... Dico ... Etenim (or Enim) ... Ergo' (1654b: ii–viii) in the Latin treatise and 'Soit (or Soient) … Je dis que … Car … Donc' [Let ... I state that ... Since ... Therefore] (1665b: 3–10) in the French treatise.[209] However, just as not every proposition contains every element of the logical structure, nor does each consequence contain each element of the linguistic structure. Fourteen of the consequences in both treatises begin with the 'Sit/Sint' or 'Soit/Soient' statement, which, in turn, is followed in each case by the statement 'Dico' or 'Je dis que'. 'Car' and 'Etinem' or 'Enim' are used at least once in every consequence, sometimes at the beginning of the expository material. They are usually followed by 'ergo', in ten propositions in the Latin treatise, and by 'donc', in eleven of the propositions in

[209] The pattern 'Sint, dico, enim, ergo' is not used as much in many of the other treatises as it is in the *Triangulus arithmeticus*. It is used extensively in the *Combinationes* and the *De numerorum continuorum*, for example, but less frequently in the *Numeri figurati* and other treatises. The French equivalent, 'Soit (or Soient), je dis que, car, donc' is used in the *Usage pour les combinaisons*, but less frequently elsewhere (1665c: 7–8).

the French treatise; in addition, ‘igitur’ is used once for ‘therefore’ in the Latin treatise while ‘or’ is used in two propositions in the French treatise, and both ‘donc’ and ‘or’ are used in the final proposition. ‘Ainsi’ [thus] is also used to introduce the final statement in four propositions in the French treatise.

The third consequence in the *Triangulus arithmeticus* and the equivalent fourth consequence in the *Traité du triangle arithmétique* provide good examples of the full demonstration. In the Latin version this is presented as follows:

> Sit quævis cellula, ξ. Dico ξ–1 æquari R + θ + ψ + φ + λ + π + σ + G [...]. Etenim ξ æquatur [...] λ + R + ω. Sed ω æquatur, π + θ + C, et, C æquatur σ + ψ + B, et B æquatur G + φ + A, et A æquatur unitati. Igitur, ξ æquatur, λ + R + π + θ + σ + ψ + G + φ + unitate
>
> [Let there be some cell, ξ. I state that ξ–1 equals R + θ + ψ + φ + λ + π + σ + G (...).
> Since ξ equals (...) λ + R + ω. But ω equals π + θ + C, and C equals σ + ψ + B, and B equals G + φ + A, and A equals unity. Therefore, ξ equals λ + R + π + θ + σ + ψ + G + φ + unity] (1654b: iii).[210]

Mathematically, the demonstration is presented in similar fashion in the French version, though the layout, using braces, makes the successive stages easier for the reader to grasp:

> ‘Soit une cellule quelconque ξ, je dis que ξ–G égale R + θ + ψ + φ + λ + π + σ + G […].
> Car ξ égale λ + R + ω.
>
> $$\lambda + R + \underbrace{\omega}_{\pi + \theta + \underbrace{C}_{\sigma + \psi + \underbrace{B}_{G + \varphi + \underbrace{A}_{G}}}}$$
>
> Donc ξ égale λ + R + π + θ + σ + ψ + G + φ + G’.
>
> [Let there be some cell, ξ. I state that ξ–G equals R + θ + ψ + φ + λ + π + σ + G (…).

[210] Similar use of the symbols as algebraic terms can be found in the treatises that refer directly to the principal treatises, i.e. the *Combinationes* (1665e: 24–29), the *Usage pour les combinaisons* (1665c: 7–8) and the *Usage pour les partis*. (1665d: 7–13).

Since ξ equals λ + R + ω (...).
Therefore, ξ equals λ + R + π + θ + σ + ψ + G + φ + G] (1665b: 4).

As with Pascal's decision to name the terms for definition in the *Traité du triangle arithmétique*, the use of the first-person singular stands out in these examples and in the majority of Pascal's demonstrations in both versions of the treatise. Pascal's practice contrasts both with the other case-study works and with the *Elements*: the propositions in the *Harmonicorum libri* and *Harmonie universelle* are written as third-person singular descriptions of musical and mathematical facts. The same is also largely true of the *Cursus* and *Cours*, except where Hérigone provides demonstrations with the use of symbols and on the rare occasions when, as discussed in section 3.4.2, he uses the first-person singular or plural. Euclid introduces his demonstrations with an initial 'Let ...' that serves the same introductory function as Pascal's 'Sit/Sint' and 'Soit/Soient', before presenting the rest of the demonstration in the passive voice. Pascal also uses the passive voice in some demonstrations but his significant deployment of the first-person singular imbues him and the demonstrations with a greater level of authority and serves to include the less scholarly reader.

The examples above also reveal another aspect of Pascal's practice, one that he often seemed reluctant to engage with: the use of symbols for generalised algebra in his demonstrations. Descotes believes that this dislike of symbols arose in part from Pascal's style: '[c]e qui caractérise [...] Pascal, c'est le souci d'une science à la fois audacieuse, convaincante et capable d'être transmise avec une rhétorique claire et lumineuse' [what characterises Pascal (…) is the desire for science to be bold, convincing and able to be conveyed using clear and illuminating rhetoric] (1993: 444). Pascal's style in both languages was designed therefore to be understood; the dislike of symbols came from a fear of a lack of mathematical clarity. He was adhering to Euclid's approach of using 'langue naturelle' [natural language] with 'aucune représentation symbolique véritable' [no real symbolic representation], where letters may be used but act simply as labels (Serfati 1998: 240). Pascal himself stated in the *Potestatum numericarum summa* that he only used 'letters' when enunciations became too difficult for him to do without them (1665e: 35).

This strategy informs his use of symbols in the *Triangulus arithmeticus*. As he explains in the treatise's final notice: 'Cellulas per litteras designavi non autem per numeros in ipsis cellulos insertos, ad evitandam confusionem quæ ex similitudine numerorum in variis cellulis insertorum orta fuisset' [I have named the cells using letters and not the numbers placed in the cells in order to avoid the confusion that would have been caused by the same number being placed in various cells] (1654b: ix). Each symbol simply replaces the number in the same cell and has no general applicability. This includes ξ, the sum of the terms in the example above. The statement about using letters for numbers does not, however, appear in the *Traité du triangle arithmétique*, almost certainly because Pascal realised that the introduction of the 'arbitrary' generator meant that the symbols in the Arithmetic Triangle no longer had a purely representative function. In the French treatise, the symbols can represent an infinite number of possible values, depending on the generator. This general signification means that they are manipulated as algebraic terms, added together to equal a single general term, ξ.[211]

It should be noted that, despite his apparent reluctance to use algebraic symbolisation, not only does Pascal add terms together, as in the examples above, and, occasionally, subtract the letters from the Arithmetic Triangle, thereby treating them as generalised numbers, but, in the Latin treatise alone, he also multiplies them, showing an awareness of the new algebra introduced by Viète and found in the *Cursus*. In *Consect. 10*, Pascal states that '[d]ico C æquari, 2 θ, et etiam Dico C, æquari 2 B' [I state that C equals 2θ, and I also state that C equals 2B] (1654b: v). This algebraic formulation is replaced in the *Traité du triangle arithmétique* by the non-algebraic 'Soit une cellule de la Dividente, C. Je dis qu'elle est double de, θ, et aussi de, B' [Let there be a cell from the Divident, C. I state that it is double θ, and also (double) B] (1665b: 6). It is likely that Pascal felt that the use of a new and unusual term, such as 2θ, would be off-putting for the non-specialist audience for the *Traité du triangle arithmétique*, while the specialists for whom the *Triangulus arithmeticus* was intended would not be expected to find it difficult to contend with.

[211] For example, in the original Arithmetic Triangle with generator equal to 1 only, the letter B in row 3, column 2, stands for the number 3, as shown in the diagram. In the generalised Arithmetic Triangle, the letter B could stand for any multiple of 3, depending on the choice of arbitrary generator. If G = 2, for example, B = 6; if G = 3, B = 9. In fact, for all choices of G, B = 3G, and all of the letters in the cells are equal to aG (i.e. $a \times G$), where a is the number in the cell.

Pascal’s distrust of symbols can also be seen in his patchy use in demonstrations in both texts of signs for arithmetic and algebraic manipulation, many of which had not been fixed by the middle of the seventeenth century. As can be seen in the examples above, Pascal deploys the addition and subtraction signs in the same way in both texts: he uses the Christian cross in a vertical position for addition and the standard sign for subtraction.[212] He does not use symbols for multiplication, division or equality, however, preferring verbal explanations in both languages instead. For multiplication and division, he uses the words ‘in’ and ‘par’ in Latin, and their equivalents ‘en’ and ‘par’ in French. In the ‘Problem’ at the end of the Latin treatise, for example, the multiplication and division required to find the number in cell ξ is expressed as follows: ‘igitur est ξ quotiens divisionis ipsius 3 in 4 in 5 in 6, per 4 in 3 in 2 in 1’ [therefore ξ is the quotient of the division of 3 by 4 by 5 by 6 by 4 by 3 by 2 by 1] (1654b: ix). This is expressed in a similar fashion, but slightly more clearly, thanks to the addition of the term for ‘product’, in the French version: ‘donc ξ, est le quotient de la division du produit de 3 en 4 en 5 en 6, par le produit de 4 en 3 en 2 en 1’ [therefore ξ is the quotient of the division of the product of 3 by 4 by 5 by 6 by the product of 4 by 3 by 2 by 1] (1665b: 11).[213] For equality, Pascal prefers to use the Latin terms ‘æquatur’ and ‘æquantur’ (1654b: ii–v, vii–viii) and the equivalent French terms ‘égale’ and ‘égalent’ or ‘est égal(e) à’ (1665b: 2–6, 9) rather than a symbol.[214]

In addition to using rigorous, mathematical demonstrations in his propositions, with and without symbols and signs, Pascal also provides statements of mathematical rhetoric designed to support his demonstrations.[215] Mathematical rhetoric is used to support the demonstrations in all of the consequences, linking the text together and persuading the reader of the rigour of the argument. The statements include references to previously demonstrated

---

[212] Pascal uses the subtraction sign when it is needed throughout the two collections of treatises. He generally does the same with the addition sign, but also uses the word ‘plus’ in the *Usages pour les binômes et apotomes* (1665d: 14) and refers to it as the ‘signum affirmationis’ [sign of affirmation, or positivity] in the *Potestatum numericarum summa* (1665e: 38).

[213] The required calculation is the division of $3 \times 4 \times 5 \times 6$ by $4 \times 3 \times 2 \times 1, i.e.\ \xi = \frac{3\times4\times5\times6}{4\times3\times2\times1}$. It should be noted that, in place of verbal explanation, Pascal uses a comma for multiplication in algebraic expressions in the *Usages pour les binômes et apotomes* (1665c: 14) and the *Potestatum numericarum* (1665e: 35–36).

[214] Pascal uses the verbs for equality in preference to a symbol throughout the treatises in both collections: ‘æquatur’ is used in the *Numeri figurati* (1654a: 4–5) and *Combinationes* (1665e: 26–27), and ‘égale’ in the *Traité des ordres numériques* (1665e: 4), for example.

[215] ‘Mathematical rhetoric’ is used in this section in the sense defined in section 2.2.2.

consequences; declarations of how consequences follow from each other and, in some cases, are therefore obvious; generalisations of consequences; and specific examples. The use of these statements varies between the two treatises: Pascal does not place them in the same locations in the treatises, but relies on them in both. Expressions such as ‘ex præcedente’ (1654b: viii) and ‘par la precedente’ (1665b: 3) [by the previous (consequence)], ‘*ex* 1*. consect.*’ [from the first consequence] (1654b: iii) ‘par la douziesme consequence’ [from the twelfth consequence] (1665b: 9), and ‘*ex hypoth.*’ (1654b: vi) and ‘par l’hypothese’ (1665b: 7) [from the hypothesis] can be found throughout both treatises, providing cohesion between different elements in the texts and contributing to the logical structure of the treatises.[216]

A similar function is fulfilled by the many statements that declare that something has been demonstrated. Such declarations abound in both treatises: the pairs ‘Sic ostendetur’ (1654b: iii) and ‘Ainsi l’on monstrera [...] que’ (1665b: 4) [Thus it will be shown that] and ‘*ex ostensis*’ [*from what has been shown*] (1654b: vi) and ‘comme il est monstré’ [as is shown] (1665b: 7) are direct equivalents in the treatises. However, these phrases appear more frequently in the French treatise: equivalents of ‘parce qui est monstré’ (1665b: 4) [from what is shown] and ‘La mesme chose se demonstre de mesme’ [The same thing can be demonstrated in the same way] (1665b: 5) are not found in the Latin version. It seems likely that Pascal added more of these statements to facilitate understanding for his less scholarly readers: signalling where and how something has been demonstrated allows readers to make connections in the text that they might otherwise not be able to recognise and persuades them that the argument is following a logical course.

In addition, as was seen in the previous case studies, there are a number of statements in both treatises that add coherence and persuasiveness to a demonstration by declaring the obviousness of mathematical reasoning. The fourth proposition in the *Triangulus arithmeticus*, for example, contains the explanation ‘in secunda basi, manifeste æquantur, φ, σ’ [in the second base, φ,

[216] This is a technique that Pascal uses throughout all of the treatises in the two collections. This includes references between treatises, which are found most frequently in the Latin treatises, such as ‘*ex triang. arith, ad initium*’ [*from the beginning of the* (Treatise on the) Arithmetic Triangle] in the *Numeri figurati* (1654a: 5), ‘ex demonstratis in tractatu de ordinibus numericis’ [as demonstrated in the treatise on number sequences] in *De numerorum continuorum* (1665e: 14, 16), and ‘ex consect. 11 tr. arith.’ [from consequence 11 in the *(Treatise on the) Arithmetic Triangle*] in the *Combinationes* (1665e: 29).

σ are clearly equal] (1654b: iii), while the fifth proposition in the *Traité du triangle arithmétique* contains the equivalent 'dans la seconde base φ σ, il est evident que les deux cellules reciproques, φ, σ, sont égales entre elles' [in the second base, it is clear that the two reciprocal cells φ and σ are equal to each other], before going on to state about the third and fourth bases that 'il est visible' [it is clear] that they are equal to each other and that two other cells 'sont visiblement égales' [are clearly equal] (1665b: 4).[217] The latter examples above cannot be found in the Latin treatise, while similar statements from the Latin treatise do not appear in the French treatise. This is the case, for example, with 'unde patet' [from which it clearly follows that] (1654b: iv), which begins the corollary in the Latin treatise and therefore does not appear in the French treatise.

The final rhetorical device is used to round off demonstrations in some of the propositions in both treatises, though it appears more frequently in the *Triangulus arithmeticus* than the *Traité du triangle arithmétique*: the statements 'Quod Erat Demonstrandum' (1654b: iii), frequently abbreviated to 'Q. E. D.' [what needed to be demonstrated] (1654b: iii, vi, viii), and 'Quod, Erat Faciendum Et Demonstrandum' [what needed to be done and demonstrated] (1654b: ix) occur throughout the Latin treatise while their French equivalent, 'ce qu'il falloit demonstrer', only appears twice in the French version (1665b: 7 and 10) and never in abbreviated form.[218] 'Quod Erat Demonstrandum', its Latin abbreviation and its French equivalent are used to support the authority of the author of the treatises and to convince readers of the mathematical accuracy of the arguments contained in them.

There are many other examples of the use of mathematical rhetoric to support deductive reasoning to be found in both treatises, particularly statements of generalisation and exemplification. As with the rhetorical structures and phrases set out above, most generalisations are common to both

[217] Similar formulations are used in a number of the treatises in both collections: 'Manifestum est' [It is clear that] is used in the *Numeri figurati* (1654a: 4), and 'Hoc manifestum est' [This is clear] in the *Combinationes* (1665e: 23), for example. There are similar formulations, such as with the phrase 'Facilis est solutio' [Solving it is easy] from the *Numeri figurati* (1654a: 5), which is rendered as 'La solution en est facile' [The solution is easy] in the *Traité des ordres numériques* (1665e: 2).

[218] 'Q.E.D.' and 'Q.E.F.E.D.' are used throughout the *De numerorum continuorum* (1665e: 14, 17), the *Potestatum numericarum summa* (1665e: 38), the *De numeris multiplicibus* (1665e: 44), and the *Combinationes* (1665e: 24, 27, 28, 32, 33). The full French version, 'Ce qu'il falloit demonstrer' is used in the French-only *Usage pour les partis* (1665d: 10) and as a translation of 'Q.E.D.' from lemma 4 in the *Combinationes* in lemma 4 in the *Usage pour les combinaisons* (1665c: 8), though in the latter case located in a slightly different part of the lemma.

treatises, but are not necessarily always expressed in the same way. The discussion about the sums of the rows of the Arithmetic Triangle in the seventh and eighth consequences of the *Triangulus arithmeticus* and *Traité du triangle arithmétique* respectively are a case in point. In both consequences, Pascal states that the sum of the terms in the nth row is equal to the nth power of 2, but uses different expressions to convey the generality of the propositions: the abbreviation 'etc' in the Latin treatise and the full phrase 'Et ainsi à l'infiny' [And so on to infinity] in its French equivalent (1654b: iv, 1665b: 5).[219]

Just as the generalisations discussed above are frequently signified by an abbreviation in the Latin text and a fuller statement in the French text, the same is true with examples Pascal provides to illustrate his demonstrations. The abbreviation 'v.g.' is used throughout the Latin text (1654b: i, v, vii, ix) and 'par exemple' [for example] (1665b: 2, 6, 7, 9, 11) in the French treatise.[220] The Latin and French expressions are frequently used as equivalents of each other, particularly in the consequences, where 'par exemple' is used as a direct translation of 'v.g'. In other parts of the text, including the definitions section, 'v.g.' and 'par exemple' are used independently of each other. Pascal's use of the full expressions 'par exemple' for 'v.g.', 'et ainsi à l'infiny' instead of 'etc.', and 'ce qu'il falloit demonstrer' instead of 'Q.E.D.' suggests a desire to ensure that the reader of the French text is not put off by the use of abbreviations, as used in the Latin text.[221]

It is clear from this survey of Pascal's demonstrations in the *Triangulus arithmeticus* and *Traité du triangle arithmétique* that his main focus was on

---

[219] Expressions used to generalise results to an infinite number of cases abound in the treatises in both collections. There are numerous examples of the use of 'etc.' to imply infinite generalisation in both languages, including in the *Numeri figurati* (1654a: 3, 5), the *Usage pour les ordres numériques* (1665c: 2), the *Traité des ordres numériques* (1665e: 3) and the *Combinationes* (1665e: 24, 28). Other expressions used in the Latin texts include 'Et sic in infinitum' [And thus infinitely] in, amongst others, the *Numeri figurati* (1654a: 9) and the *De numericis ordinibus* (1665e: 9), and 'Et sic deinceps in infinitum' [And thus successively infinitely], in the *De numeris multiplicibus* (1665e: 43). In the French texts, 'Et ainsi à l'infiny' [And thus to infinity] is used twice in the *Usage pour les binômes et apotomes* (1665d: 15, 16) and as a direct translation of 'Et sic in infinitum' in the *Usage pour les ordres numériques* (1665c: 2).

[220] The same distinction between the abbreviation 'v.g.' in the Latin texts and the full wording of 'par exemple' in the French texts can be seen throughout the other treatises in both collections: v.g. is used more than twenty-five times in the Latin treatises, but 'par exemple' is used far more sparingly in the French treatises. 'Verbi gratia' is used in full in some instances, including in the *Combinationes* (1665e: 23, 24); on the first occasion, it is translated by 'par exemple' in the *Usage pour les combinaisons* (1665c: 5).

[221] In comparison with Pascal, it is noticeable that Hérigone and Mersenne do not generally use abbreviated forms. On the rare occasions when they do, they mostly abbreviate well-known parts of the mathematical structure of their Latin texts. Mersenne, for example, refers to propositions, books and chapters in the *Liber de cantibus* as 'propos.', 'lib.' and 'cap.' (1636a: 114, 131). Hérigone refers to Euclid's *Elements* as 'Elem.' in Latin but by its full title in French (1634f: 102). He also writes out 'Quod erat demonstrandum' in full in both languages (1634g: 270). This comparison is not exhaustive, but it gives an indication of the relatively unusual nature of Pascal's Latin abbreviations.

achieving clarity and demonstrating his authority as a mathematician in both languages. This explains why the internal structure of the demonstrations in the two treatises is very similar, irrespective of the language used. The minimal use of symbols supports his approach: the impact is similar in both treatises although, on the rare occasions when Pascal does use more complex symbolism, he confines its use to the Latin treatise, suggesting that he is aware of the need not to alienate his French readers. There are differences in the use of the phrases used throughout the demonstrations in both texts to add coherence to their logical structure. Like the symbols, these generally serve to make the French treatise more readable and less forbidding for non-specialists, but do not detract from Pascal's overall aim to provide mathematical demonstrations that convince his readers of the truth of his statements. The two different approaches reflect Pascal's understanding of how people receive information, as set out in *De l'art de persuader* and explained at the beginning of section 5.4: while the focus of both texts is the use of 'vérités démontrées' [proven truths] that will appeal to the readers' 'entendement' [understanding, or reason], he recognises in writing the French version that he also needs to appeal to their 'volonté' [will] using a range of rhetorical devices (1991: 413). As with the comparative analysis of the structures of the treatises and Pascal's use of definitions as part of his rhetorical method in the French and Latin treatises, it is clear in this examination of his use of mathematical demonstration that there are distinct differences between the two texts. These differences are significant enough for the French text not to be regarded as a faithful translation of the Latin text. However, they are not sufficiently substantial to allow a conclusion that the texts are not bilingual versions covering the same material, with the second text standing as a rewritten version of the first.

5.5 Chapter conclusion

The investigation into the *Triangulus arithmeticus* and the *Traité du triangle arithmétique* presents a complex picture. The two texts clearly present a great deal of commonality in structure and content. This is not surprising, since the *Traité du triangle arithmétique* was intended as a French-language introduction to the same material that was presented in the Latin text, and both treatises are the products of Pascal's method, as set out in the two parts of the *De l'esprit géométrique*, designed to provide a structure for defining terms and proving propositions in mathematical treatises, irrespective of the language used. As Hokenson and Munson have stated, consideration of the similarities, or continuities, between versions of texts is no less important than examination of their differences in determining the nature of self-translated texts (2007: 4). For this reason, it will be helpful to consider the similarities and differences separately.

The similarities between the two texts include a large degree of overlap between the opening definitions sections of the two treatises and between the majority of the propositions that make up the rest of the texts. The correspondence between the texts also extends to techniques employed by Pascal, such as his use of contrasting typefaces to allow the words being defined in the definitions sections to stand out in contrast to the rest of the text. The structures of the propositions in the two treatises also show a large degree of closeness, alongside a level of conformity with seventeenth-century expectations. Many of the devices used to add cohesion to the two texts, and many of the symbols (and terms used in the place of symbols), are also common to both texts. The level of overlap is reinforced by much of the mathematical terminology used: the status of French as a Romance language derived from Latin facilitates the transfer of ideas from Latin to French by means of significant numbers of equivalent terms.

Despite all of the similarities between the two versions of the treatise, there are a number of differences between them, some more significant than others. In self-translation terms, the relevance of the differences is their impact on the relationship between the two versions of the treatise. The importance of the presence of the diagram of the Arithmetic Triangle with the French treatise and its absence from the Latin treatise is unclear: a lack of insight into Pascal's intentions with regard to the diagram's inclusion with the Latin treatise means that it is impossible to say with any degree of certainty whether its inclusion with the *Traité du triangle arithmétique* alone is significant. The same cannot, however, be said about the change in the nature of the generator of the Arithmetic Triangle: from being limited to a single value of 1 in the *Triangulus arithmeticus*, it becomes 'arbitrary', capable of taking the value of any natural number in the *Traité du triangle arithmétique*. Although Pascal chooses to use examples in both texts based on the unit generator alone, the impact of changing the generator in this way in the short period between writing the Latin and French versions of the treatise is considerable. The change causes an additional consequence to be added to the French text, putting all of the other consequences out of alignment, and a number of notices to be added to the French text to remind the reader that, despite the fact that the examples are based on the unit generator alone, the consequences apply to any arbitrary generator. In addition, the change in the generator causes the emphasis in the method for generating the numbers in the cells of the Arithmetic Triangle to shift from using lists of figurate numbers to adding values in adjoining cells.

While the change to the generator leads to the most significant structural and textual differences between the two versions of the treatise, they are not the only differences. The other changes introduced between writing the Latin and French texts all clearly suggest that Pascal had his new, less scholarly audience in mind when he wrote the *Traité du triangle arithmétique*. While both versions of the treatise can be considered as highly rigorous mathematical texts, this is more the case for the *Triangulus arithmeticus* than for the *Traité du triangle arithmétique*. Some of the more technical aspects of the Latin treatise have been altered to make the French treatise less challenging: the disappearance of mathematical labels such as the vertex Z and triangle 1Z1 from the *Triangulus arithmeticus*, for example; the less technical terms used to describe the Arithmetic Triangle's columns and column headers in the French treatises; the use of full wording in the French treatise where abbreviations are used in the Latin text; the omission of complex algebra from the French treatise; and the use of braces to clarify the demonstrations in the second treatise. In addition, the use of the first-person singular to introduce new terminology in the *Traité du triangle arithmétique* adds a level of authority to convince the readers of the French text of the importance of both the mathematical content and Pascal's status as a mathematician as well as to include them in the community of mathematicians.

Despite the overall similarity between the two versions of the treatises, the differences between them, as outlined in the previous paragraph, particularly those relating to the change of generator, point to a conclusion that the *Traité du triangle arithmétique* is, as Mesnard suggests, a reworking of the *Triangulus arithmeticus*, rather than a faithful translation. The *Traité du triangle* *arithmétique* is a near-simultaneous reframing of the *Triangulus arithmeticus* that makes the French text more an update to a work in progress than a complete adaptation. The relationship between Pascal's two principal treatises on the Arithmetic Triangle constitute an example of bilingual writing that reflects every dimension of the composite definition of self-translation provided in section 1.1. The similarities between the two versions mean that the French version of the treatise can be considered as a self-translation within Bassnett's definition of the practice as texts 'reshaped for a new readership' (2013a: 287). Moreover, the *Traité du triangle arithmétique* can also be considered a self-translation within both Popovič's definition as 'the translation of an original work into another language by the author himself' (1976: 19) and Hokenson and Munson's description of the bilingual text as 'authored by a writer who can compose in different languages and who translates his or her texts from one language into another' (2007: 1). Furthermore, the *Traité du triangle arithmétique* can also be considered as a second original text, as suggested by Singer (quoted by Grutman and Van Bolderen 2014: 330).

In addition, the question of the fate of different versions raised by Santoyo (2013a: 34) is relevant in the case of the *Traité du triangle arithmétique*, as the French version of the text has a very different history as a printed text than the Latin version. The *Traité du triangle arithmétique* was printed as part of a collection that can be considered as separate from the collection containing the *Triangulus arithmeticus*, as demonstrated in section 5.2.2 but, crucially, unlike the Latin version of the treatise, it was distributed and read, particularly in France, as well as in other parts of Europe, by people who had no knowledge of the *Triangulus arithmeticus*. This means that, despite being written second, the *Traité du triangle arithmétique* is the better-known version of the principal treatise on the Arithmetic Triangle, and the *Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière*, the partial self-translation of the first collection is the more widely recognised collection of treatises on the Arithmetic Triangle.

Conclusion

My investigation into three cases of Latin and French self-translation of mathematical texts in mid-seventeenth-century France has examined the key 'what', 'when', 'why' and 'how' questions of self-translation and has revealed in very general terms that the texts' authors produced bilingual works at similar stages in their scholarly careers, had similar motivations for doing so, but created very different pairs of works, for differing personal reasons, and used a range of self-translation practices.

Consideration of the place of the case-study works within the mathematicians' complete written output shows some differences and a number of similarities. First, while the *Cursus mathematicus* and *Cours mathématique* and the *Harmonie universelle* and *Harmonicorum libri* were Hérigone's and Mersenne's only self-translated pairs of works, the same was not true for Pascal, who wrote Latin and French versions of a letter for a Europe-wide competition and two bilingual accounts of the same competition as well as the bilingual treatises on the Arithmetic Triangle. Even in Pascal's case, however, self-translation was the exception rather than the rule, accounting for a relatively low proportion of his complete output. Examination of the stage in the writers' careers when the self-translations were written reveals that both Mersenne and Pascal composed their bilingual works well over a decade after their first books were published, at a time when they were established contributors to the French and European scientific communities. A lack of knowledge of Hérigone's life and his limited number of published works make it impossible to draw conclusions about his case.

The choice of language for composition across each author's complete works show some similarities: although Hérigone's known written works are too restricted in nature for conclusions to be attempted, Mersenne and Pascal wrote in both Latin and French. Both writers composed the majority of their books in French: Pascal's scientific and religious works were all written in the language, and the same was true of most of Mersenne's non-mathematical books. Pascal reserved Latin solely for mathematical works. Although some were written in French, he told Fermat that he found writing about combinatorics easier in Latin, so it is no surprise that he wrote the treatises on the Arithmetic Triangle in Latin first before rewriting some of them to popularise the ideas contained in them. Mersenne's translations of Galileo's works were in French, but his mathematical collections and his later works were published in Latin. By contrast, the majority of his musical works were published in French; in fact, the *Harmonicorum libri* was the only one written in Latin, an exceptional case explained by the status of the *Harmonie universelle* and *Harmonicorum libri* as the culmination of a lifetime's work on music.

As with examination of which works the case-study mathematicians created in bilingual versions and the stages in their writing careers that they wrote them, there are patterns of similarity and difference to be discerned when explaining why those books were self-translated. Of the reasons identified in Renaissance and Early Modern self-translation research, one in particular stands out in the case studies: the wish to reach as large and varied an audience as possible. This desire to appeal to multiple audiences was a combination of a range of historical linguistic and societal forces that shaped production and reception of the case-study works. The survey of early to mid-seventeenth-century mathematical works based on the data collected in appendix 1 showed that the choice between Latin and French, caused by the changing relationship between the two languages in France, was a significant factor in publication of mathematical books of all kinds during this period. While some works were more likely to be published in French — recreational and practical mathematics books, for example — and others in Latin, especially higher-prestige books on more scholarly subjects such as astronomy, many authors were able to choose between the two languages. In some cases — involving nine works by seven different mathematicians and including the case-study works — the authors chose to compose their works in both languages. Another significant reason for the bilingual situation in publishing was the changing audiences for mathematical works: the development of a small but increasingly educated French-speaking audience, the growing importance of the audience in the Republic of Letters with some knowledge of French but with Latin as their *lingua franca*, and a largely bilingual audience of French mathematicians who attended scientific and mathematical cabinets and academies, such as Mersenne's, and wrote many of the mathematical works of the period.

There is clear evidence in Mersenne's letter to Peiresc that he set out to write separate musical works for distinct French- and Latin-reading audiences within and outside France. Pascal's situation is equally clear-cut: the fact that he wrote new texts and rewrote existing ones to provide practical applications of the Arithmetic Triangle in the second, mixed-language collection of treatises, while leaving the pure mathematics elements in the original Latin-only collection untranslated, strongly implies that his motivation was provided by the potential new French-speaking audience for the French parts of the second collection. Similarly, Hérigone's decision to place his two texts side-by-side suggests that he intended his work as a bilingual teaching tool for a range of audiences, possibly in Europe as well as France. The writers therefore had similar, but not identical, motivations for creating their works as self-translations that can be explained by a range of historical factors. However, while the historical factors identified in this research clearly helped create conditions that were favourable to self-translation of mathematical texts during this period, there was nothing inevitable about the writers' choice, as the other ninety-three monolingual works in appendix 1 attest.

The lack of inevitability in mathematicians' decision-making in this period can also be seen in other aspects of the case-study works, including the relationships between the two versions of their texts and the writers' translational practice. From the information available, it seems clear that two of the pairs of works were created simultaneously — the *Cursus mathematicus* and *Cours mathématique* on the one hand and the *Harmonie universelle* and *Harmonicorum libri* on the other — while Pascal's two principal treatises on the Arithmetic Triangle were created near-simultaneously, within a month of each other. The simultaneous creation of the pairs of works by Hérigone and Mersenne makes it difficult to identify an original work in either case. The *mise-en-page* of the *Cursus mathematicus* and *Cours mathématique* strongly suggests that Hérigone saw the Latin version as the original and the French version as a translation, but their simultaneous publication makes a definitive conclusion impossible. The situation is clearer with Mersenne's work: the high level of similarity of overall content and structure at the level of the full works, linked to clear differences in the detail of the content at the level of the books imply strongly that they can be seen as complementary dual versions of a single work, not as original and translation, source text and target text. This is the case despite Mersenne's description to Peiresc of the Latin books as an abridged version of the French volumes. In Pascal's case, the sequence of events in composition makes it clear that the Latin text was the original version. However, the fate of the treatises on the Arithmetic Triangle means that the mixed-language collection and the French version of the principal treatise are much better known than the Latin ones: it was the mixed-language collection that was printed in multiple copies, was found amongst Pascal's possessions on his death, and became known throughout Europe, particularly France and Belgium. The evidence seems to suggest that, by contrast, it was the Latin version of Mersenne's work that dominated: it was the version that was reissued after his death, probably because of demand amongst the Latin-reading audience that was not there for the French version. As a consequence, there are approximately three times as many copies of the *Harmonicorum libri* known to be held in European and North American research libraries as copies of the *Harmonie universelle*, and a greater proportion of the copies of the Latin work held outside France. The picture is more mixed with the *Cursus*: while it was recorded as read by a wider range of European than French mathematicians in the seventeenth century, current holdings suggest approximately equal ownership in France and the rest of Europe.

Although similarities can be discerned in the stages of their careers when two of the three authors wrote their books, and in the reasons why they wrote them as bilingual works, the same degree of similarity is not evident in the finished products, either at the level of the whole works or the sections examined in more detail in the thesis. Hérigone's multi-volume work, for example, consists largely of bilingual text displayed in a columnar and interlinear *mise-en-page*, where the texts in the two languages are very similar, though not identical, even where Hérigone has taken the content from the works of other mathematicians. By contrast, Mersenne's work comprises two versions that have many similarities in general content and structure, both at the level of the complete works and a single pair of books within them, the *Liber de cantibus* and *Livre des chants*, but many differences and discrepancies are discernible between the structure and content of equivalent books when they are examined in more detail. In many senses, Pascal's pair of works is a case apart: the decision to write new treatises for the second collection and to translate only specific treatises, or parts of treatises, resulted in what can only be described as a partial self-translation. However, Pascal's translation methodology in the principal treatises in the collections places his practice firmly between the methods used by the other two writers: except where the need to accommodate the change to the generator is concerned, the text of the *Traité du triangle arithmétique* is largely similar to the original Latin *Triangulus arithmeticus*. The forced changes make the correspondence between the two versions less faithful than in Hérigone's case and a clear case of rewriting; it is nevertheless more faithful than Mersenne's practice, which can only be described as significant rewriting.

There is evidence from the detailed study of the two versions of Hérigone's Practical Arithmetic, Mersenne's book on songs and Pascal's principal treatise on the Arithmetic Triangle that the decisions about how closely the Latin and French texts should correspond had differing impacts on how the authors treated their different audiences, but that there are nevertheless common threads running through the three self-translations. I have shown in this thesis that all three authors modified their French texts in some respects to accommodate what they almost certainly perceived as a less mathematically sophisticated audience than the Latin readers of the Republic of Letters. Hérigone's decision to ensure a high level of correspondence between his texts means that differences between the texts are rare. They are nevertheless discernible: omissions and additions in the text show him making the French text slightly easier to deal with than the Latin text. Mersenne's approach, in creating dual versions of his book of songs, for example, allows him to vary much more: the examples he uses to illustrate mathematical points and generalise his findings, the titles and layout of his tables, and the mathematical terminology associated with combinatorics, all show him also making the French version slightly more straightforward than its Latin equivalent. Pascal's practice in the *Traité du triangle arithmétique*, where the French text is closer to the Latin than in Mersenne's case, also demonstrates that he made similar adjustments, altering some of the more technical aspects of his treatise for the French audience: using more accessible terminology and labelling for the

Arithmetic Triangle and a more comprehensible layout for his demonstrations, for example.

Some of the modifications to the different versions of the case-study texts can be attributed to variations in the use of rhetorical strategies and techniques. In general, however, it can be said that there is significant overlap in the use of rhetoric in the pairs of case-study works and between the case-study authors. The most overt use of rhetoric can be seen in the methods for demonstration introduced by Hérigone and Pascal. Part of Pascal's method focuses on clear definitions, recalling Aristotle's methodology, but, unlike Aristotle, Pascal is solely concerned with nominal definitions. Both Hérigone and Pascal, the latter implicitly in a separate explanatory work, *De l'esprit géométrique*, invoke classical authority in the form of Euclid and Proclus in their desire to embed rigorous methods of proof, which are themselves structured in a similar way to the parts of a speech in classical rhetoric.

The rhetorical appeal to authority can be seen elsewhere in the case-study works, in Hérigone's address to the reader and in his chronology of great mathematicians in the first and sixth volumes respectively of the *Cursus*, and in Mersenne's copious use of citation and self-citation. Hérigone seeks to persuade the reader of the value of his new method and the need for his work to be so comprehensive by citing classical authorities in the address, supporting his efforts through the use of techniques from classical rhetoric elsewhere in the *Cursus*, and subtly reinforcing his status by implying that he belongs in the same company as the great mathematicians in his chronology. In a similar manner, in both the *Livre des chants* and the *Liber de cantibus*, Mersenne refers to a range of classical, mediaeval and early modern scholars and sources to convince the reader of the quality of his own work. He reinforces his status through self-citation, referencing his own works throughout both books. Pascal, on the other hand, chooses to dispense with a preface justifying and positioning his work, and does not call on any authorities of any kind in the principal treatises on the Arithmetic Triangle, preferring simply to mention other members of Mersenne's academy.

All three mathematicians use techniques of mathematical rhetoric to persuade their readers that their mathematical demonstrations are proceeding in a clear and logical fashion to a conclusion in which the audience can have confidence. Although a number of examples of the use of mathematical rhetoric differ in the texts in the two languages, particularly in the case of Mersenne's writing, but also discernible in Pascal's practice, all three case-study authors use mathematical rhetoric to the same ends in both Latin and French: to convince the reader that something has been clearly demonstrated using previously explained properties, that the next step is also clear and obvious and that the conclusion of the demonstration has therefore been correctly arrived at and relates back to the original proposition.

My conclusions about the 'when', 'what', 'why' and 'how' of the production of the pairs of bilingual case-study texts are necessarily general: the diversity of motivation and practice across the three case studies shows that specific findings apply to these three case studies alone. It is probable that some of my findings would also apply to the other mid-seventeenth-century bilingual mathematical works in the corpus in appendix 1, but it is by no means certain that they could be said to apply to all of those works. Nor is it certain that they would apply to bilingual mathematical works composed in different eras, where a different range of historical factors would help shape writers' motivation and practice. What my conclusions have shown, however, is that there are types of self-translation that have not been considered in the self-translation research literature. This applies particularly to partial self-translation, the most apt description of Pascal's second collection of treatises on the Arithmetic Triangle, and to Hérigone's practice in compiling and rewriting other mathematicians' work to create his own bilingual work. In both cases, the absence of the types of translation — partial self-translation and self-translation of non-original work — from the research literature can be explained by the lack of variety in self-translation research topics. The continuing focus on modern literary self-translation inevitably means that practices seen in other types of writing will be missed.

My investigation has shown the need for a formal methodology for self-translation research, based on the methods used in the wide range of investigations already undertaken. This would need to be comprehensive, so that it includes all potential types of self-translation, and flexible, in order to incorporate newly discovered features of self-translation. It should be possible to use existing research to establish a framework for self-translation research that incorporates these and other desirable criteria. My research has shown a similar need for a comprehensive and dynamic definition of self-translation. I have proposed a definition based on aspects of the conclusions of self-translation researchers that served to provide a full understanding of what constitutes self-translation and bilingual writing as a background to the case studies. As with a self-translation research methodology, it should be possible to extend this definition further using conclusions from existing and future research into self-translation from the full range of genres and eras outlined in chapter 1.

My research has also revealed avenues for research within and beyond the narrow field of mid-seventeenth-century mathematical Latin-French self-translation. Further research that incorporates all of Pascal's bilingual works would be of great interest, as it would shed light on his practice across the rest of the self-translations in the second collection of treatises on the Arithmetic Triangle and the works on the cycloid competition. Similarly, investigating other seventeenth-century mathematical self-translations, including the pairs of works identified in appendix 1, by Girard, Leurechon, Morin and Niceron, would provide more insight into the practice in mathematics in this specific period. This would help open out research into mathematical self-translation in other locations and centuries, where there are likely to be a number of unexplored examples. My thesis has also demonstrated the urgent need for more research into all types of non-literary self-translation, particularly in the pre-modern period, as self-translated texts in a wide range of subjects and all texts written before 1900 have been relatively neglected up to now.

Finally, my research has also raised questions within the other fields identified in the introduction: the history of the book and the history of mathematics. There is little evidence within research literature about collaborative practices in self-translation. In relation to the case studies, the only evidence was an isolated comment from a correspondent about Mersenne's support system and a general suggestion relating to help received by compilers. Research is required in both book history and self-translation to investigate the extent to which writers of bilingual works relied on other writers and researchers in creating their works and on printers, publishers, booksellers and other members of the book trade in making them available to the public. Within the history of mathematics, little attention has been paid to the role of self-translation in the transfer and dissemination of mathematical knowledge, as exemplified by Edwards's and Bosmans' treatment of the *Triangulus arithmeticus*. Section 2.2.1 demonstrated the important role translation has played throughout history in spreading mathematical knowledge and concepts, yet the role of self-translation is rarely, if ever, discussed. This thesis has succeeded in highlighting the self-translation of mathematical texts in mid-seventeenth-century France, as it set out to do. It has also raised a number of other matters relating to the works of the case-study authors, self-translation of mathematical texts in general, the history of the book and the history of mathematics for future researchers to explore in greater depth.

Appendices

Appendix 1: The major seventeenth-century French mathematicians and their works

Section A: The mathematicians and their works

In order to carry out the analysis of languages used in seventeenth-century mathematical works published in France, which I present in section 2.1.3, I have collated, in figure 13 below, details of the major mathematical works composed by the most significant French mathematicians active in the period between 1610 and 1665. This is the period stretching from the decade before Mersenne began publishing to the year in which Pascal's treatises on the Arithmetic Triangle were published posthumously. The period therefore includes the dates of composition and publication of all of the mathematical works written by Hérigone, Mersenne and Pascal and their contemporaries. Starting the list in the 1610s allows perspective to be gained when analysing the languages used in mathematical texts written and/or published during the period in which the case-study works were written, i.e. 1634–1654.

The mathematicians whose works have been tabulated were chosen on the basis of the 'Chronological List of Mathematicians' located on the website of the Department of Mathematics and Computer Science at Clark University and maintained by Professor David E. Joyce.[222] The criteria for inclusion in this appendix are a modified version of the criteria for inclusion in the Clark University list. All of the mathematicians in the appendix have biographies in at least one of the following: as mathematicians (in the seventeenth-century understanding of the term) in the 1981 edition of the *Dictionary of Scientific*

[222] The full Clark University list can be found at https://mathcs.clarku.edu/~djoyce/mathhist/chronology.html. The mathematicians included in the list have:

- Entries in the 1970–1978 edition of the *Dictionary of Scientific Biography*.
- Biographies in the MacTutor History of Mathematics archive at the School of Mathematical and Computational Sciences of the University of St Andrews, at https://mathshistory.st-andrews.ac.uk/.
- Biographies excerpted from W. W. Rouse Ball's *A Short Account of the History of Mathematics* and included on the 'History of Mathematics' website maintained by Dr David R. Wilkins from the School of Mathematics at Trinity College, Dublin, at https://www.maths.tcd.ie/pub/HistMath/HistMath.html.
- Biographies compiled by Richard S. Westfall, Professor Emeritus in the Department of History and Philosophy of Science at Indiana University, which appear in the Catalogue of the Scientific Community, which is part of the Galileo Project at Rice University.

Biography, in the MacTutor archive maintained at the University of St. Andrews, or in both. The other two sources of biographies in the Clark University list have not been included in the criteria because they contain fewer, less detailed biographies than the two sources consulted.

The works included in figure 13 are those mentioned in the mathematicians' entry in either the *Dictionary of Scientific Biography* or the MacTutor History of Mathematics website, or in both. Other, less important works may also have been published but not mentioned in the biographies, and so have not been included. In addition to the published works, a small number of other works are known to have been completed during this time, but were not published until later. These are generally works by better-known scholars, including Fermat, Descartes and Pascal. These unpublished works have been included in the appendix and marked with an asterisk.

Many of the mathematicians whose works appear in the tables below were scholars in a number of disciplines and would not necessarily have made the same distinction between disciplines as we do today. Books by the mathematicians on any of the subjects named in the 'Editorial decisions and definitions' section have therefore been included in figure 13. Works have, however, been excluded if they are primarily non-mathematical in nature.

A small number of the major mathematicians identified did not publish significant works of mathematics in the designated period, including the following: Antoine Arnauld (1612–1694), Adrien Auzout (1622–1691), Pierre de Carcavi (*c.* 1600–1684), Claude François Milliet Dechales (1621–1678), Philippe de la Hire (1640–1718), Bernard Lamy (1640–1715), Gabriel Mouton (1618–1694), Claude Mylon (*c*. 1618–*c.* 1660), Jacques Ozanam (1640–1717), Étienne Pascal (1588–1651), Jean Picard (1620–1682), and Jean Richer (1630–1696).

Name	**Major works**					
Bachet de Méziriac, Claude-Gaspar (1581–1638)	*Problemes plaisans et delectables, qui se font par les nombres* (1612)					
Beaugrand, Jean (*c.* 1595–1640)	*Geostatice, seu de vario pondere gravium* (1636)					
Billy, Jacques de (1602–1679)	*Abrege des preceptes d'algebre (*1637)	*Nova geometriæ clavis algebra (*1643)	*Tabulæ lodoicææ* (1656)	*Tractatus de proportione harmonica* (1658)	*Diophantus geometria* (1660)	*Opus astronomicum* (1661)
Bosse, Abraham (1602–1676)	*La pratique du trait a preuves de Mr. Desargues, pour la coupe des pierres en l'architecture* (1643)	*La maniere universelle de Mr. Desargues, pour poser l'essieu, et placer les heures et autres choses aux cadrans au soleil* (1643)	*Traité des manieres de graver en taille douce sur l'airin par le moyen des eaux fortes et des vernix durs et mols* (1645)	*Maniere universelle de Mr. Desargues pour pratiquer la perspective par petit-pied, comme le geometral* (1648)	*Moyen universel pour pratiquer la perspective sur les tableaux, ou surfaces irregulieres* (1653)	*Representations geometrales de plusieurs parties de bastiments faites par les reigles de l'architecture antique* (1659)
Bosse, Abraham	*Traité des manieres de dessiner les ordres de l'architecture antique en toutes leurs parties* (1664)					
Boulliau, Ismaël (1605–1694)	*De natura lucis (*1638)	*Philolai, sive dissertationis de vero systemate mundi libro IV* (1639)	*Astronomia philolaïca* (1645)	*De lineis spiralibus* (1657)		

Name	Major works						
Buot, Jacques (died *c.* 1675)	*Usage de la roue de proportion* (1647)						
Debeaune, Florimond (1601–1652)	*Notes briefves sur la methode algebraique de Mr D. C.* (*c.* 1639)[223]						
Desargues, Girard (1591–1661)	*Une methode aisee pour apprendre et enseigner a lire et escrire la musique* (1636)[224]	*Exemple de l'une des manieres universelles du S.G.D.L. touchant la pratique de la perspective sans emploier aucun tiers point, de distance ny d'autre nature, qui soit hors du champ de l'ouvrage* (1636)	*Brouillon project d'une atteinte aux evenemens des rencontres du cone avec un plan* (1639)	*Brouillon project d'exemple d'une maniere universelle du S.G.D.L., touchant la pratique du traict a preuves pour la coupe des pierres en l'architecture* (1640)			
Descartes, René du Perron (1596–1650)	*Progymnasmata de solidorum elementis** (*c.* 1630)	*Algebræ specimen quoddam* (1628)	*La Dioptrique* (1637)[225]	*La Géométrie* (1637)			
Fabri, Honoré (1607–1688)	*Tractatus physicus du motu locali* (1646)	*Synopsis geometrica* (1649)	*De linea sinuum et cycloide* (1659)	*De maximis et minimis in infinitum* (1659)	*Brevis synopsis trigonometriæ planæ* (1659)		

[223] The *Notes briefves* were translated into Latin as the *Notæ breves* and added to the first Latin edition of Descartes's *La Géométrie* (*Geometria*, 1649) (Costabel 1981a: 616). I have included it in the same decade as publication of the *Géométrie*

[224] Published as the first proposition in the 'Livre sixiesme de l'art de bien chanter' of Mersenne's *Harmonie universelle* (1965d: 332–42).

[225] Both *La Dioptrique* and *La Géométrie* were published with the *Discours de la méthode*.

Name	Major works					
Fermat, Pierre de (1601–1665)	*Ad locos planos et solidos isagoge** (*c.* 1636)	*Methodus ad disquirendam maximam et minimam et de tangentibus linearum curvarum** (*c.* 1638)				
Frenicle de Bessy, Bernard (*c.* 1605–1675)	*Solutio duorum problematum circa numeros cubos et quadratos (*1657)					
Gassendi, Pierre (1592–1655)	*Mercurius in sole visus et venus invisa Parisiis, anno 1631* (1632)	*De motu impresso a motore translato* (1642)	*De apparente magnitudine solis humilis et sublimis (*1642)	*De proportione, qua gravia decidentia accelerantur* (1646)	*Institutio astronomica* (1647)	
Girard, Albert (1595–1632)	*Tables des sinus, tangentes et secantes, selon le raid de 100000 parties* (1626)	*Tabulæ sinuum, tangentium, et secantium, ad radium 100,000* (1626)	*Invention nouvelle en l'algebre (*1629)			
Hardy, Claude (*c.* 1598–1678)	*Examen de la duplication du cube, et quadrature du cercle* (1630)	*Refutation de la maniere de trouver un quarre egal au cercle* (1638)				
Henrion, Denis (or Didier) (*c.* 1580–*c.* 1632)	*Memoires mathematiques recueillis et dressez en faveur de la noblesse françois* (1613–27)	*Traicté des triangles spheriques* (1617)	*L'usage du compas de proportion* (1618*)*	*Canon manuel des sinus, touchantes et coupantes* (1619)	*Cosmographie ou traicté general des choses tant celestes qu'elementaires* (1620*)*	*Collection, ou Recueil de divers traictez mathematiques* (1620)

Name	Major works					
Henrion, Denis (or Didier)	*Sommaire de l'algebre, tres-necessaire pour faciliter l'interpretation du dixiesme livre d'Euclide* (1623)	*Traicté des logarithmes* (1626)	*Logocanon , ou Regle proportionelle* (1626)	*Nottes sur les recreations mathematiques* (1627)	*L'usage du mecometre* (1630)	
Hérigone, Pierre (died *c.*1643)	*Cursus mathematicus* (1634–42)	*Cours mathematique* (1634–42)				
Lalouvère, Antoine de (1600–1664)	*Quadratura circuli et hyperbolæ segmentorum (*1651)	*Propositiones geometricæ sex* (1658)	*Propositio 36α excerpta ex quarto libro de cycloide nondum edito* (1659)	*Veterum geometria promota in septem de cycloide libris* (1660)		
Le Tenneur, Jacques-Alexandre (died after 1652)	*Traité des quantitez incommensurables* (1640)	*De motu naturaliter accelerato tractatus physico-mathematicus* (1649)				
Leurechon, Jean (*c.* 1591–1670)	*Pratiques de quelques horloges et du cylindre* (1616)	*Ratio facillima describendi quam plurima et omnis generis horologia brevissimo tempore* (1618)	*Brevis tractatus de cometa viso mensibus novembri et decembri anno elapso* (1619)	*Discours sur les observations de la comete de 1618* (1619)	*Selectæ propositiones in tota sparsim mathematica pulcherrimæ* (1622)	*Recreation mathematique, composee de plusieurs problemes plaisants et facetieux* (1626)
Mersenne, Marin (1588–1648)	*Synopsis mathematica* (1626)	*Traité de l'harmonie universelle* (1627)	*Questions inouïes, ou récréations des savants* (1634)	*Traité des mouvements et de la chute des corps pesants* (1634)	*Les Mecaniques de Galilée* (1634)	*Questions harmoniques* (1634)

Name	Major works					
Mersenne, Marin	*Les Preludes de l'harmonie universelle, ou Questions curieuses* (1634)	*Harmonicorum libri* (1636)	*Harmonie universelle* (1636–37)	*Les Nouvelles pensees de Galilee* (1639)	*Universæ geometriæ, mixtæ mathematicæ synopsis* (1644)	*Cogitata physico-mathematica* (1644)
Mersenne, Marin	*Novarum observationum physico-mathematicorum* (1647)	*L'Optique et la catoptrique* (1651)				
Morin, Jean-Baptiste (1583–1656)	*Astronomicarum domorum cabala detecta* (1623)	*Famosi et antiqui problematis de telluris motu* (1631)	*Trigonometriæ canonicæ libri tres* (1633)	*Astronomia jam a fundamentis integre et exacte restituta* (1640)	*La science des longitudes* (1647)	*Trigonometrie canonique* (1657)
Morin, Jean-Baptiste	*Astrologia gallica* (1661)					
Mydorge, Claude (1585–1647)	*Examen du livre des recreations mathematiques et de ses problemes* (1630)	*Prodromi catoptricorum et dioptricorum, sive conicorum operis* (1631)				
Niceron, Jean-François (1613–1646)	*La perspective curieuse, ou, Magie artificielle des effets merveilleux* (1638)	*L'Interpretation des chiffres* (1641)	*Thaumaturgus opticus seu admiranda* (1646)			

Name	Major works					
Pascal, Blaise (1623–1662)	*Essai pour les coniques* (1640)	*Triangulus arithmeticus** (1654)	*Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere* (1654/1665)	*Historia trochoidis* (1658)	*Histoire de la roulette* (1658)	*Suite de l'histoire de la roulette* (1658)
Pascal, Blaise	*Historia trochoidis, sive cycloidis, continuatio* (1658)	*Lettres de A. Dettonville* (1659)				
Petit, Pierre (1594 or 1598–1677)	*L'usage ou le moyen de pratiquer par une regle toutes les operations du compas de proportion* (1634)	*Dissertation sur la nature des cometes* (1665)				
Roberval, Gilles Personne de (1602–1675)	*Traité de mechanique* (1636)	*Aristarchi Samii de mundi systemate, partibus et motibus ejusdem libellus* (1644)				
Vernier, Pierre (1584–1638)	*La Construction, l'usage, et les proprietez du quadrant nouveau de mathematique* (1631)					

Figure 13: The major mathematical works published in France, 1610–1665

In figure 14 below, the treatises in figure 13 have been placed in chronological order to facilitate the analysis of trends in language use over time.

***Title* (year)** (1612–26)	***Title* (year)** (1627–36)
Problemes plaisans et delectables, qui se font par les nombres (1612) (K)	*Nottes sur les recreations mathematiques* (1627) (K)
Memoires mathematiques recueillis et dressez en faveur de la noblesse françoise, 2 vols (1613–1627) (N)	*Traité de l'harmonie universelle* (1627) (D)
Pratiques de quelques horloges et du cylindre (1616) (M)	*Algebræ specimen quoddam* (1628) (A)
Traicté des triangles spheriques (1617) (N)	*Invention nouvelle en l'algebre (*1629) (A)
Ratio facillima describendi quam plurima et omnis generis horologia brevissimo tempore (1618) (M)	*Examen du livre des recreations mathematiques et de ses problemes* (1630) (K)
L'usage du compas de proportion (1618*)* (L)	*Examen de la duplication du cube, et quadrature du cercle* (1630) (C)
Canon manuel des sinus, touchantes et coupantes (1619) (F)	*L'usage du mecometre* (1630) (L)
Discours sur les observations de la comete de 1618 (1619) (E)	*Progymnasmata de solidorum elementis** (*c.* 1630) (C)
Brevis tractatus de cometa viso mensibus novembri et decembri anno elapso (1619) (E)	*La Construction, l'usage, et les propriétez du quadrant nouveau de mathématiques* (1631) (L)
Cosmographie ou traicté general des choses tant celestes qu'elementaires (1620*)* (R)	*Prodromi catoptricorum et dioptricorum, sive conicorum operis (*1631) (H)
Collection, ou Recueil de divers traictez de mathematiques (1620) (O)	*Famosi et antiqui problematis de telluris motu* (1631) (E)
Selectæ propositiones in tota sparsim mathematica pulcherrimæ (1622) (C)	*Mercurius in sole visus et venus invisa Parisiis, anno 1631* (1632) (E)
Astronomicarum domorum cabala detecta (1623) (E)	*Trigonometriæ canonicæ libri tres* (1633) (F)
Sommaire de l'algebre tres-necessaire pour faciliter l'interpretation d'Euclide (1623) (A)	*L'usage ou le moyen de pratiquer par une règle toutes les opérations du compas de proportion (*1634) (L)
Tables des sinus, tangentes et secantes, selon le raid de 100000 parties (1626) (F)	*Les Preludes de l'harmonie universelle, ou Questions curieuses* (1634) (D)
Logocanon , ou Regle proportionelle (1626) (L)	*Questions inouïes, ou récréations des savants* (1634) (K)
Tabulæ sinuum, tangentium, et secantium, ad radium 100,000 (1626) (F)	*Traité des mouvements et de la chute des corps pesants* (1634) (G)
Traicté des logarithmes (1626) (P)	*Questions harmoniques* (1634) (D)
Synopsis mathematica (1626) (O)	*Les Mecaniques de Galilée* (1634) (G)
Recreation mathematique, composee de plusieurs problemes plaisants et facetieux (1626) (K)	*Cursus mathematicus/ Cours mathématique* (1634–42) (O)

***Title* (year)** (1636–40)	***Title* (year)** (1640–47)
Traité de mechanique (1636) (G)	*Traité des quantitez incommensurables* (1640) (B)
Exemple de l'une des manieres universelles du S.G.D.L. touchant la pratique de la perspective, sans emploier aucun tiers point, de distance ny d'autre nature, qui soit hors du champ de l'ouvrage (1636) (C)	*Brouillon project d'exemple d'une maniere universelle du S.G.D.L., touchant la pratique du traict a preuves pour la coupe des pierres en l'architecture* (1640) (C)
Harmonicorum libri (1636) (D)	*Essai pour les coniques* (1640) (C)
Geostatice, seu de vario pondere gravium (1636) (G)	*L'Interprétation des chiffres (*1641) (B)
Une methode aisee pour apprendre et enseigner a lire et escrire la musique (1636) (D)	*De apparente magnitudine solis humilis et sublimis (*1642) (E)
*Ad locos planos et solidos isagoge** (*c.* 1636) (C)	*De motu impresso a motore translato* (1642) (G)
Harmonie universelle (1636–37) (D)	*La pratique du trait a preuves de Mr. Desargues, pour la coupe des pierres en l'architecture* (1643) (J)
La Dioptrique (1637*)* (H)	*La maniere universelle de Mr. Desargues, pour poser l'essieu, et placer les heures et autres choses aux cadrans au soleil* (1643) (J)
*La Géométrie (*1637) (C)	*Nova geometriæ clavis algebra* (1643) (A)
*Abrege des preceptes d'algebre (*1637) (C)	*Universæ geometriæ, mixtæ mathematicæ synopsis* (1644) (O)
Refutation de la maniere de trouver un quarre egal au cercle (1638) (C)	*Cogitata physicomathematica* (1644) (O)
La perspective curieuse, ou, Magie artificielle des effets merveilleux (1638) (C)	*Aristarchi Samii de mundi systemate, partibus et motibus ejusdem libellus* (1644) (G)
*De natura lucis (*1638) (H)	*Astronomia philolaïca* (1645) (E)
*Methodus ad disquirendam maximam et minimam et de tangentibus linearum curvarum** (*c.* 1638) (C)	*Traité des manieres de graver en taille douce sur l'airin par le moyen des eaux fortes et des vernix durs et mols* (1645) (J)
Brouillon project d'une atteinte aux evenemens des rencontres du cone avec un plan (1639) (C)	*Tractatus physicus du motu locali* (1646) (G)
Philolai, sive dissertationis de vero systemate mundi libro IV (1639) (E)	*Thaumaturgus opticus seu admiranda* (1646) (H)
Les Nouvelles pensees de Galilée (1639) (G)	*De proportione, qua gravia decidentia accelerantur* (1646) (G)
Notes briefves sur la methode algebraique de Mr D. C. (*c.* 1639) (C)	*Institutio astronomica* (1647) (E)
Astronomia jam a fundamentis integre et exacte restituta (1640) (E)	*La science des longitudes* (1647) (Q)

***Title* (year)** (1647–58)	***Title* (year)** (1658–65)
Novarum observationum physico-mathematicorum (1647) (O)	*Suite de l’histoire de la roulette* (1658) (C)
Usage de la roue de proportion (1647) (L)	*Historia trochoidis, sive cycloidis, continuatio* (1658) (C)
Maniere universelle de Mr. Desargues pour pratiquer la perspective par petit-pied, comme le geometral (1648) (J)	*Tractatus de proportione harmonicæ* (1658) (D)
*Synopsis geometrica (*1649) (C)	*Propositiones geometricæ sex* (1658) (C)
De motu naturaliter accelerato tractatus physico-mathematicus (1649) (G)	*Representations geometrales de plusieurs parties de bastiments faites par les reigles de l’architecture antique* (1659) (J)
L'Optique et la catoptrique (1651) (H)	*Brevis synopsis trigonometriæ planæ* (1659) (F)
*Quadratura circuli et hyperbolæ segmentorum (*1651) (C)	*De maximis et minimis in infinitum* (1659) (C)
Moyen universel pour pratiquer la perspective sur les tableaux, ou surfaces irregulieres (1653) (J)	*Propositio 36α excerpta ex quarto libro de cycloide nondum edito* (1659) (C)
Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière (1654/1665) (B)	*Lettres de A. Dettonville* (1659) (C)
*Triangulus arithmeticus** (1654) (B)	*De linea sinuum et cycloide (*1659) (C)
Tabulæ lodoicææ (1656) (E)	*Diophantus geometria* (1660) (C)
*Solutio duorum problematum circa numeros cubos et quadratos (*1657) (B)	*Veterum geometria promota in septem de cycloide libris* (1660) (C)
De lineis spiralibus(1657) (C)	*Astrologia gallica* (1661) (I)
Trigonometrie canonique (1657) (F)	*Opus astronomicum* (1661) (E)
Historia trochoidis (1658) (C)	*Traité des manieres de dessiner les ordres de l’architecture antique en toutes leurs parties* (1664) (J)
Histoire de la roulette (1658) (C)	*Dissertation sur la nature des comètes* (1665) (E)

Key to types of works (numbers of works of each type are given in brackets)

A	Algebra (4)	G	Mechanics (10)	M	Gnomonics (2)
B	Number theory (5)	H	Optics/catoptrics (5)	N	Geometry of sphere (2)
C	Geometry (28)	I	Astrology (1)	O	General (7)
D	Music (7)	J	Architecture (7)	P	Logarithms (1)
E	Astronomy (13)	K	Recreational mathematics (5)	Q	Navigation (1)
F	Trigonometry (6)	L	Use of instruments (6)	R	Cosmography (1)

Figure 14: The major mathematical works, 1610–1665, in chronological order

The overall picture across the six decades can be seen in figure 15:

Decade[226]	Latin works	French works	Total
1610s	2	7	9
1620s	5	10	15
1630s	12	23	35
1640s	15	10	25
1650s	13	8	21
1660s	4	2	6
Total	51	60	111[227]

Figure 15: The languages of the major mathematical works composed in France, 1610–1665

Section B: Self-translated mathematical works (1610–1665)

Seven of the mathematicians in the list in section A above wrote the following works as bilingual texts, composing nine pairs of works between them:

- Albert Girard: *Tables des sinus, tangentes et secantes, selon le raid de 100000 parties*, which contains the *Traicté succinct de la trigonométrie* (1626), and *Tabulæ sinuum, tangentium, et secantium, ad radium 100000* (1626), which contains the *Kort tractaet van de drie-houck-handel*;
- Pierre Hérigone: *Cursus mathematicus* and *Cours mathématique*, 6 vols (printed together, 1634–42);
- Jean Leurechon: *Brevis tractatus de cometa viso mensibus novembri et decembri anno elapso* and *Discours sur les observations de la comete de 1618* (both 1619)
- Marin Mersenne: *Harmonicorum libri/Harmonicorum instrumentorum libri IV* (1636), and *Harmonie universelle* (1636–1637);
- Jean-Baptiste Morin: *Trigonometriæ canonicæ libri tres* (1633), and *Trigonométrie canonique* (1657)

[226] Where multi-volume works were published in more than one year, the year of publication of the first volume has been taken as the date for the entire work. The lack of absolute precision in the year, or even the decade, of production or publication should not affect the purpose of this table, which is to show the overall trend in publishing over a period of fifty-six years.
[227] There are 110 works in figures 14 and 15. However, I have counted Hérigone's *Cursus mathematicus* and *Cours mathématique* as two works, one in Latin and one in French, hence the total of 111 in figure 13.

- Jean-François Niceron: *La perspective curieuse, ou, Magie artificielle des effets merveilleux* (1638) and *Thaumaturgus opticus, seu admiranda* (1646)
- Blaise Pascal: *Triangulus arithmeticus* (1654, unpublished) and *Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière* (1654, published 1665); *Historia trochoidis* and *Histoire de la roulette* (both 1658); *Suite de l'histoire de la roulette* (1658) and *Historia trochoidis, sive cycloidis, continuatio* (1658, unpublished)

Notes

Eight of the nine pairs of bilingual works were written in Latin and French. Despite its Latin title, the second version of Girard's work was written in Flemish.

Two of the pairs of bilingual works contained logarithmic and trigonometric tables and short treatises on how to use them in calculations.

Jean Beaugrand's *Geostatice*, which was composed solely in Latin, is often referred to in French as the *Géostatique* and so is often erroneously assumed to be a bilingual work.[228]

Section C: Composition of the major mathematical works

This section contains the composition — the number of pages taken up by the main text, dedications and prefaces or notices addressed to the reader — of those mathematical works included in the table in section A and available for analysis in online digital libraries, generally on the Gallica and Google Books websites.[229] The purpose of the section is to provide information for comparison with the case-study works, particularly Pascal's *Triangulus mathematicus* and *Traité du triangle arithmétique* in section 5.3.1. Pages other than the main text (T), dedications (D) and prefaces or notices (P) have not been included in this analysis.

---

228 Beaugrand's entry in the *Dictionary of Scientific Biography* incorrectly states that his publications include 'Géostatique (Paris 1636), pub. in Latin as *Geostatica* (Paris, 1637)' (Nathan 1981: 542). In fact, it was the Latin *Geostatice* that was published in 1636. The error seems to stem from contemporary scholars referring to the Latin work in French: Mersenne in 1636 in the ***Livre de l'utilité de l'harmonie***, where he referred to the conclusions of Beaugrand 'dans sa Geostatique' (1965e: 61) and Descartes in a letter to Mersenne, where he referred to Beaugrand as 'l'auteur de la *Geostatique*' (Descartes 1960: 344).

229 Gallica's digital library can be found at https://gallica.bnf.fr/ and the Google Books equivalent at https://books.google.com/.

Name	Title	No. of pages		
		T	D	P
Bachet de Méziriac, Claude-Gaspar	*Problemes plaisans et delectables, qui se font par les nombres* (1612)	247	5	8
Beaugrand, Jean	*Geostatice, seu de vario pondere gravium* (1636)	36		
Billy, Jacques de	*Nova geometriæ clavis algebra (*1643)	493	4	9
Billy, Jacques de	*Tabulæ lodoicææ* (1656)	186	6	1
Billy, Jacques de	*Opus astronomicum* (1661)	516	7	21
Billy, Jacques de	*Tractatus de proportione harmonicæ* (1658)	99	3	
Boulliau, Ismaël	*De natura lucis (*1638)	155	4	14
Boulliau, Ismaël	*De lineis spiralibus* (1657)	56	3	3
Desargues, Girard	*Brouillon project d'une atteinte aux evenemens des rencontres du cone avec un plan* (1639)	32		
Descartes, René	*La Dioptrique* (1637)	153		
Descartes, René	*La Géométrie (*1637)	117		1
Fabri, Honoré	*Tractatus physicus du motu locali* (1646)	446	2	3
Fabri, Honoré	*Synopsis geometrica (*1649)	506	10	1
Fabri, Honoré	*De linea sinuum et cycloide* (1659)	39	2	
Gassendi, Pierre	*Mercurius in sole visus et venus invisa Parisiis, anno 1631* (1632)	47		
Gassendi, Pierre	*De motu impresso a motore translato* (1642)	159		
Gassendi, Pierre	*De apparente magnitudine solis humilis et sublimis (*1642)	207		
Gassendi, Pierre	*De proportione, qua gravia decidentia accelerantur* (1646)	318		
Gassendi, Pierre	*Institutio astronomica* (1647)	312	4	2
Girard, Albert	*Traicté succinct de la trigonométrie* (1626)	53		2
Girard, Albert	*Kort tractaet van de drie-houck-handel* (1626)	68		
Girard, Albert	*Invention nouvelle en algebre (*1629)	64	2	
Hardy, Claude	*Examen de la duplication du cube, et quadrature du cercle* (1630)	32		2
Henrion, Denis or Didier	*Memoires mathematiques recueillis et dressez en faveur de la noblesse françoise, 2 vols* (1613–1627)	1250	7	12
Henrion, Denis or Didier	*L'Usage du compas de proportion* (1618)	290	6	15
Henrion, Denis or Didier	*Canon manuel des sinus, touchantes et coupantes* (1619)	73	3	3

Name	Title	No. of pages		
		T	D	P
Henrion, Denis or Didier	*Cosmographie ou traicté general des choses tant celestes qu'elementaires* (1620)	822	2	
Hérigone, Pierre	*Cursus mathematicus/ Cours mathématique*, 6 vols (1634–42)	3418	4	23
Lalouvère, Antoine de	*Quadratura circuli et hyperbolæ segmentorum* (1651)	639	6	5
Lalouvère, Antoine de	*Veterum geometria promota in septem de cycloide libris* (1660)	404	4	7
Leurechon, Jean	*Brevis tractatus de cometa viso mensibus novembri et decembri anno elapso* (1619)	24	2	
Leurechon, Jean	*Discours sur les observations de la comete de 1618* (1619)	20	1	
Leurechon, Jean	*Selectæ propositiones in tota sparsim mathematica pulcherrimæ* (1622)	36		
Leurechon, Jean	*Recreation mathematique, composee de plusieurs problemes plaisants et facetieux* (1626)	194	2	2
Mersenne, Marin	*Traité de l'harmonie universelle* (1627)	487	9	7
Mersenne, Marin	*Questions inouïes, ou récréations des savants* (1634)	180	5	2
Mersenne, Marin	*Traité des mouvements et de la chute des corps pesants* (1634)	24	3	3
Mersenne, Marin	*Les Mecaniques de Galilée* (1634)	88	7	2
Mersenne, Marin	*Questions harmoniques* (1634)	276	7	8
Mersenne, Marin	*Les Preludes de l'harmonie universelle, ou Questions curieuses* (1634)	224	5	2
Mersenne, Marin	*Harmonicorum libri* (1636)	360	3	9
Mersenne, Marin	*Harmonie universelle* (1636–37)	1484	16	30
Mersenne, Marin	*Cogitata physico-mathematica* (1644)	706	20	50
Mersenne, Marin	*L'Optique et la catoptrique* (1651)	134		6
Morin, Jean-Baptiste	*Famosi et antiqui problematis de telluris motu* (1631)	136	4	2
Morin, Jean-Baptiste	*Trigonometriæ canonicæ libri tres* (1633)	108	3	2
Morin, Jean-Baptiste	*La science des longitudes* (1647)	61	6	
Morin, Jean-Baptiste	*Trigonometrie canonique* (1657)	108	3	3
Morin, Jean-Baptiste	*Astrologia gallica* (1661)	784	3	3

Name	Title	No. of pages		
		T	D	P
Mydorge, Claude	*Examen du livre des recreations mathematiques et de ses problemes* (1630)	386		7
Mydorge, Claude	*Prodromi catoptricorum et dioptricorum, sive conicorum operis* (1631)	308	3	4
Niceron, Jean-François	*La perspective curieuse, ou, Magie artificielle des effets merveilleux* (1638)	120	5	7
Niceron, Jean-François	*L'Interprétation des chiffres* (1641)	90	4	
Niceron, Jean-François	*Thaumaturgus opticus seu admiranda* (1646)	120	5	8
Pascal, Blaise	*Lettres de A. Dettonville* (1659)	131		
Pascal, Blaise	*Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière* (1654/1665)	84		1
Petit, Pierre	*L'usage ou le moyen de pratiquer par une règle toutes les opérations du compas de proportion (*1634)	211	14	4
Petit, Pierre	*Dissertation sur la nature des comètes* (1645)	346	4	3
Roberval, Gilles de	*Traité de mechanique* (1636)	36	1	1
Vernier, Pierre	*La Construction, l'usage, et les propriétez du quadrant nouveau de mathématiques* (1631)	122	6	4

Figure 16: Composition of the major mathematical works, 1610–1665: text, dedications and prefatory material

Appendix 2: The Arithmetic Triangle and combinatorics

Section A: The Arithmetic Triangle

Diagrams prefiguring Pascal’s Arithmetic Triangle appear in both Hérigone’s *Cursus mathematicus* and *Cours mathématique* and Mersenne’s *Harmonie universelle* and *Harmonicorum libri*. Pascal’s diagram, from 1654, can be seen in figure 12 in section 5.3.2. Figures 17 to 19 below show Hérigone’s diagram from 1634 (1634g: 17) and Mersenne’s from shortly afterwards (1965c: 145 and 1636a: 136* respectively).

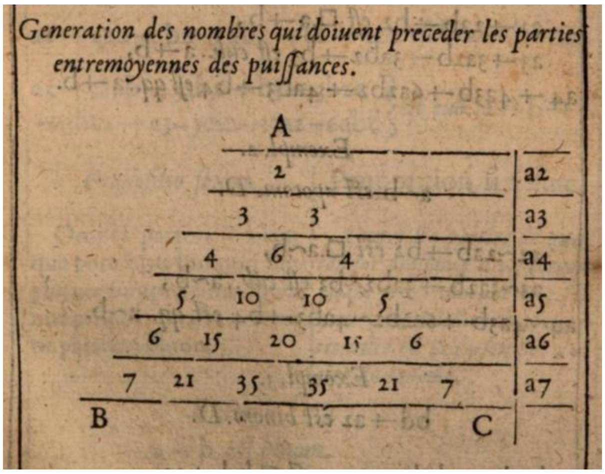


Figure 17: Hérigone’s ‘Arithmetic Triangle’

Hérigone’s version of the Arithmetic Triangle is limited to one of the three uses of the Triangle identified by Pascal: generating the numbers that precede the powers in expansions of binomial expansions.

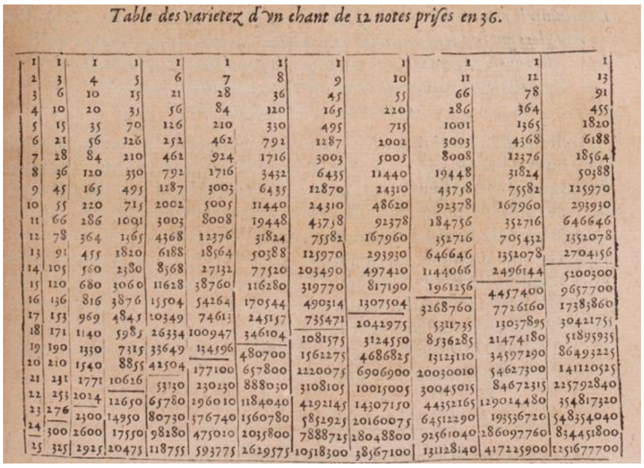


Table des varietez d'vn chant de 12 notes prises en 36.

1	1	1	1	1	1	1	1	1	1	1	1	1
2	3	4	5	6	7	8	9	10	11	12	13
3	6	10	15	21	28	36	45	55	66	78	91
4	10	20	35	56	84	120	165	220	286	364	455
5	15	35	70	126	210	330	495	715	1001	1365	1820
6	21	56	126	252	462	792	1287	2002	3003	4368	6188
7	28	84	210	462	924	1716	3003	5005	8008	12376	18564
8	36	120	330	792	1716	3432	6435	11440	19448	31824	50388
9	45	165	495	1287	3003	6435	12870	24310	43758	75582	125970
10	55	220	715	2002	5005	11440	24310	48620	92378	167960	293930
11	66	286	1001	3003	8008	19448	43758	92378	184756	352716	646646
12	78	364	1365	4368	12376	31824	75582	167960	352716	705432	1352078
13	91	455	1820	6188	18564	50388	125970	293930	646646	1352078	2704156
14	105	560	2380	8568	27132	77520	203490	497420	1144066	2496144	5200300
15	120	680	3060	11628	38760	116280	319770	817190	1961256	4457400	9657700
16	136	816	3876	15504	54264	170544	490314	1307504	3268760	7726160	17383860
17	153	969	4845	20349	74613	245157	735471	2042975	5311735	13037895	30421755
18	171	1140	5985	26334	100947	346104	1081575	3124550	8536285	21474180	51895935
19	190	1330	7315	33649	134596	480700	1562275	4686825	13123110	34597290	86493225
20	210	1540	8855	42504	177100	657800	2220075	6906900	20030010	54627300	141120525
21	231	1771	10626	53130	230230	888030	3108105	10015005	30045015	84672315	225792840
22	253	2024	12650	65780	296010	1184040	4292145	14307150	44352165	129024480	354817320
23	276	2300	14950	80730	376740	1560780	5852925	20160075	64512290	193536720	548354040
24	300	2600	17550	98280	475010	2035800	7888725	28048800	92561040	286097760	834451800
25	325	2925	20475	118755	593775	2629575	10518300	38567100	131128140	417225900	1251677700

Figure 18: Mersenne’s ‘Arithmetic Triangle’ in the Livre des chants

Tabella pulcherrima & vtilißima Combinationis duodecim Cantilenarum.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
1	1	1	1	1	1	1	1	1	1	1	1
2	3	4	5	6	7	8	9	10	11	12	13
3	6	10	15	21	28	36	45	55	66	78	91
4	10	20	35	56	84	120	165	220	286	364	455
5	15	35	70	126	210	330	495	715	1001	1365	1820
6	21	56	126	252	462	792	1287	2002	3003	4368	6188
7	28	84	210	462	924	1716	3003	5005	8008	12376	18564
8	36	120	330	792	1716	3432	6435	11440	19448	31824	50388
9	45	165	495	1287	3003	6435	12870	24310	43758	75582	125970
10	55	220	715	2002	5005	11440	24310	48620	92378	167960	293930
11	66	286	1001	3003	8008	19448	43758	92378	184756	352716	646646
12	78	364	1365	4368	12376	31824	75582	167960	352716	705432	1352078
13	91	455	1820	6188	18564	50388	125970	293930	646646	1352078	2704156
14	105	560	2380	8568	27132	77520	203490	497420	1144066	2496144	5200300
15	120	680	3060	11628	38760	116280	319770	817190	1961256	4457400	9657700
16	136	816	3876	15504	54264	170544	490314	1307504	3268760	7726160	17383860
17	153	969	4845	20349	74613	245157	735471	2042975	5311735	13037895	30421755
18	171	1140	5985	26334	100947	346104	1081575	3124550	8436285	21474180	51895935
19	190	1330	7315	33649	134596	480700	1562275	4686825	13123110	34597290	86493225
20	210	1540	8855	42504	177100	657800	2210075	6906900	20030010	54627300	141120525
21	231	1771	10626	53130	230230	888030	3108105	10015005	30045015	84672115	225792840
22	253	2024	12650	65780	296010	118404	4292145	14307150	44352165	119024480	354817320
23	276	2300	14950	80730	376740	1560780	5852925	20160075	64512290	193536720	548354040
24	300	2600	17550	98280	475020	2035800	7888725	28048800	92561040	286097760	834451800
25	325	2925	20475	118755	593775	2629575	10518300	38567100	131128140	417225900	1251677700

Figure 19: Mersenne's 'Arithmetic Triangle' in the Liber de cantibus

Mersenne's Arithmetic Triangle is also limited to one use in the *Livre des chants* and *Liber de cantibus*: to find combinations of notes, in the search for the perfect song. Mersenne's arrangement of the values in his Arithmetic Triangle moves away from the traditional triangular arrangement favoured by Hérigone (with the apex at the top) towards an arrangement where the apex is in the top left-hand corner. Placement of his results in a table makes it difficult to see them as part of what would become the Arithmetic Triangle. Nevertheless, this change in orientation is repeated by Pascal: he also places the apex of his Arithmetic Triangle in the top-left corner, but ensures the results resemble a triangle.

Section B: Combinatorics

Combinatorics — the mathematics of permutations and combinations — deals with arrangements of discrete objects, such as the letters of the alphabet, or the notes in a musical scale. Mersenne presented a number of different cases of permutations and combinations in the *Harmonie universelle* and the *Harmonicorum libri*: permutations of all objects available and of a given number of objects from those available, with and without repetition, and combinations of a given number of objects from a larger set of objects.

Permutations

Many of the examples in the *Harmonie universelle* and the *Harmonicorum libri* involve permutations. Some permutations are arrangements of all possible objects available, while others are arrangements of a selected number of the objects. Similarly, some permutations involve repeated objects, while others do not. In all cases, the same objects arranged in a different order counts as a separate arrangement, so that, for example, the two-letter arrangement AB is not the same as the arrangement BA.

Permutations with unrestricted repetitions

Arrangements using all objects available

Permutations with unrestricted numbers of repetitions include all possible arrangements of the objects available. So, for example, the number of two-letter arrangements of the letters A and B, if both letters can be used in either position, is four: AA, AB, BA, and BB. This can be calculated for any number of letters, n, using the formula n^n. In this example, therefore, there are $2^2 = 4$ permutations. As Mersenne shows, there are $8^8 = 16,777,216$ possible arrangements of the eight notes in the octave, if any note can be used as often as desired (1965c: 149).

Arrangements using a restricted number of objects

The number of two-letter arrangements of the letters A, B and C, created under the same conditions as above, is nine: AA, AB, AC, BA, BB, BC, CA, CB, and CC. In this case, the number of arrangements can be calculated using the formula n^r, where r represents the number of letters in each arrangement and n the total number of letters to choose from, as before. In this example, therefore, there are $3^2 = 9$ arrangements or permutations.

Permutations with restrictions

Most of the permutations in the *Harmonie universelle* and the *Harmonicorum libri* deal with situations where the notes quoted can only be used once each. In some cases, all of the notes available are used, while in others only a predetermined number are selected.

Arrangements using all objects available

One type of permutation involves using all of the objects available and providing all possible arrangements. So, for example, all of the possible three-letter arrangements of the letters A, B and C, when they can only be used once each, are: ABC, ACB, BAC, BCA, CAB, and CBA. The number of possible arrangements of three objects is six, which can also be found using 3![230] In general, there are $n! = 1 \times 2 \times \ldots . \times n - 1 \times n$ arrangements of n objects.

Introducing repeated elements into a group of objects reduces the number of possible arrangements, so that, for example, there are only three arrangements of three objects if one is repeated. The only three-letter arrangements of the letters A, B and B, for example, are: ABB, BAB, and BBA. In this case, the number of arrangements can be calculated as $\frac{3!}{2!} = 3$. In general, the number of arrangements of n objects where an object is repeated p times is $\frac{n!}{p!}$. There is a similar, extended formula to calculate the number of arrangements of n objects where one object is repeated p times, another object is repeated q times, and so on: $\frac{n!}{p!q!\ldots!}$. For example, the letters A, B, B, C, C, C can be arranged using all six letters in $\frac{6!}{1!2!3!} = 60$ ways, where the 6 represents the number of letters available, and the 1, 2 and 3 represent the number of As, Bs and Cs.

Arrangements using a restricted number of objects

A different use of permutations involves taking only some of the objects available and placing them in all of the possible different orders. For example, all of the possible two-letter permutations of the letters A, B, C, D and E, where each letter can be used once only, are: AB, AC, AD, AE, BA, BC, BD, BE, CA, CB, CD, CE, DA, DB, DC, DE, EA, EB, EC, ED. The twenty permutations can also be found using the general formula $P_r^n = \frac{n!}{(n-r)!}$, where P_r^n represents the number of permutations of r objects selected from the n objects available. In this case, $P_2^5 = \frac{5!}{(5-2)!} = \frac{5!}{3!} = 20$.

As with arrangements above, introducing repeated elements into a group of objects reduces the number of possible permutations. There are, for example, sixty five-letter permutations of the six letters A, B, B, B, C, C: this is obtained by dividing the number of permutations of five letters taken from six

[230] 3! is pronounced ‘three factorial’. The factorial exclamation mark is an instruction to multiply all of the natural, or counting, numbers up to and including the number in question, in this case up to 3, so that $1 \times 2 \times 3 = 6$ in this example.

available (P_5^6) by the factorials of the numbers of repeated letters (3 Bs and 2 Cs). The calculation is then $\frac{P_5^6}{3!2!} = \frac{6!}{(6-5)!} \div 3!\,2! = \frac{6!}{1!3!2!} = 60$.

In fact, the initial examples, where all available items could be selected, is a special case of this type of permutation, where all n objects available are selected and so $r = n$ and $P_r^n = P_n^n = \frac{n!}{(n-n)!} = n!$ (as $0! = 1$).

Combinations without repetitions

Mersenne deals with combinations without repetitions after permutations in the *Harmonie universelle* and the *Harmonicorum libri* and does so in less depth. As with permutations, combinations are arrangements of objects. There are two major differences, however: first, the combinations can only be selections of r objects from n available objects, and second, unlike with permutations, all arrangements that use the same letters or notes are considered to be the same arrangement. Hence, for example, the six permutations of the letters A, B, and C are considered to be a single combination ABC because the order in which the letters appear is not important. Consequently, the number of combinations of r objects from n available objects is given by a formula similar to the formula for permutations, with an extra divisor of $r!$ to take account of the lack of importance of order.

The formula for calculating the number of combinations of r objects from n available objects is therefore $C_r^n = \frac{n!}{r!(n-r)!}$. For example, the number of three-letter combinations of the seven letters A, B, C, D, E, F, G is given by $C_3^7 = \frac{7!}{3!4!} = 35$. It should be noted that the combinations C_0^n and C_n^n also have a meaning: they are both equal to 1, as the former represents the case where no objects are selected and the latter the case where all of the objects are selected (in both cases, there is one way of making the selection). This observation is important for the completeness of the Arithmetic Triangle. Hérigone omits all of the 1s from his version of the Arithmetic Triangle, while Mersenne includes only the top row (the C_n^n case, i.e. where all possible objects are selected).

Combinations are one of the three ways Pascal approaches the numbers in the Arithmetic Triangle; he also treats them as terms in number sequences (i.e. as figurate numbers when the generator equals 1) and as binomial coefficients. Combinations figure in a pair of treatises accompanying the *Traité du triangle arithmétique* and the *Triangulus arithmeticus*: *Combinationes* and *Usage du triangle arithmétique pour les combinaisons.* For example, the third row of the Arithmetical Triangle is made up of the numbers 1, 3, 3, 1, which represent the numbers of ways of selecting 0, 1, 2 and 3 objects from a total of three objects, i.e. C_0^3, C_1^3, C_2^3 and C_3^3. As Mersenne almost notes, the total number of combinations in the nth row of the Arithmetical Triangle is 2^n, so that there are $2^3 = 8$ combinations of three objects in total. For the letters A, B and C, for example, the eight combinations would be: no letters (one way of selecting no letters); A, B, C (three ways of selecting one letter); AB, AC, BC (three ways of selecting two letters); and ABC (one way of selecting three letters). Mersenne in fact stated that there are $2^n - 1$ combinations, as he did not account for the situation where no objects are selected, as noted above.

Appendix 3: Mathematical terminology

The purpose of this appendix is to provide additional information about the instance of first recorded use of Latin and French mathematical terms found in the case-study texts. I noted in section 2.2.3 that, according to Folkerts and Hauchecorne, there have been no systematic attempts to investigate the development of Latin and French mathematical terminology respectively, and that historical research into the origins of words used in mathematical writing relies instead on etymological dictionaries (Folkerts 2005: 149; Hauchecorne 2003: 223). The majority of French dictionaries, whether general or specialist, have incomplete etymological information. While the general dictionaries, both paper-based and online, are more comprehensive in scope, their focus is not specifically on the vocabulary of mathematics, and so dates of first mathematical use are not always recorded, particularly for words with several general meanings, such as ‘point’, or terms that have been replaced in mathematical vocabulary, such as ‘ajouter’ (replaced by ‘additioner’ in the late seventeenth century, according to Hauchecorne, 2003: 15). By their very nature, specialist dictionaries focus more closely on mathematical terms, but are selective in their choice of vocabulary, and also do not always provide evidence of date of first use.

I also noted in section 2.2.3 that the development of French from Latin and the consequent linguistic affinity between the languages meant that the majority of French mathematical terms can be traced back to Latin (Descotes 2008: 43). I have used the derivation of French terms from their Latin cognates as the basis for the table in figure 20 below, which supports all of the commentary on mathematical terminology in the three case studies. The table consists of a list of the French and Latin mathematical vocabulary found in the sections of the case-study works that I investigated most closely: the two versions of Hérigone’s book on Practical Arithmetic, Mersenne’s *Livre des chants* and *Liber de cantibus*, and Pascal’s *Triangulus arithmeticus* and *Traité du triangle arithmétique*. The table shows the instance of first use in French of mathematical vocabulary, where it is noted in Hauchecorne’s work, the *Petit Robert* and the CNRTL website. The difficulty of tracing the origins of most Latin terms in mediaeval and Early Modern mathematics books, other than the vocabulary mentioned in section 2.2.3, means that very few have dates of first use in print. However, as the majority of the French terms were derived from their Latin equivalents, it can be assumed that, for those terms, their first appearance in print predates the first use of the French versions of the words. Any terms whose use was not fully settled by the seventeenth century, such as ‘combination’ [permutation or combination] and ‘terme’ [term of a sequence], borrowings from other languages, such as ‘chiffre’ [number, digit, figure] and ‘zéro’ [zero], and non-cognate terms, including ‘côté’ [latus], ‘degré’ [gradus], and ‘ligne’ [rectus], are dealt with in the text of the thesis.

The following abbreviations are used in the table below: Hne (Hauchecorne), PR (*Le Petit Robert*), CNRTL (Centre National de Ressources Textuelles et Lexicales), H, M and P (Hérigone, Mersenne and Pascal), and MA (Middle Ages).

French term	Latin equivalent	Century of first use			Author	English meaning
		Hne	CNRTL	PR		
addition	additio	16	14	15	H, M	addition
aire	area		13	13	H	area
arithmétique	arithmeticus	12	12	12	H, P	arithmetic
aune (aulne)	ulnis		12		H	ell
base	basis		16		P	base (vb)
carré (quarré)	quadratum	16	16	16	M, P	square (n)
centaine	centarii		12	12	H	a hundred or so
corollaire	corollarium	17	14/17	14	H, M, P	corollary
cube	cubus	14	13		M	cube (n)
décuple	decuple		15	14	H	tenfold increase
démonstration	demonstratio	13	12	12	H, M	demonstration
dénominateur	denominator	15	15	15	H	denominator
diagonalement	diagonaliter		16	16	H	diagonally
dîme (dixme)	decimus		12	12	H	tenth part
diviser	dividare	15	16	16	M, P	divide
diviseur	divisor	15	15	13	H, M	divisor
division	divisio	15	13		H, M, P	division
dizaine	denarii		14	16	H	ten or so
double	dupla		16	11	M, P	double (n)
égaler	æquo	16		13	H, P	equal (vb)
exemple	exemplum	11	11	11	M, H, P	example
exposant	exponens	17	17	17	H	exponent
fraction	fractio	16	13	16	H	fraction
infini	infinitum	17	13	16	M	infinity
livre	libra		10	10	H	pound
méthode	methodus		16	16	H, M	method
mille	mille		11	11	M	thousand
moins	minus		12	12	P	less, minus
multiplication	multiplicatio		13	16	H	multiplication

French term	Latin equivalent	Century of first use			Author	English meaning
		Hne	CNRTL	PR		
multiplier	multiplicare				M, P	multiply (vb)
nombre	numerus	12	12	12	H, M, P	number (n)
numérateur	numerator	15	15	15	H	numerator
once	uncia		12	12	H	ounce
parallèle	parallelus	16	16	16	P	parallel
perpendiculaire	perpendicularis	16	16	16	P	perpendicular
pied	pes		12	11	M	foot
pinte	pinta		13	13	H	pint
pouce	pollex		12	12	M	inch
produit	producto	15	16	16	M, P	product
progression	progressio	17	13	13	H	sequence
proportion	proportio		14		P	proportion
proposition	propositio	13	15		H, M, P	proposition
quantième	quantus		15	14	M	how many
quotient	quotiens	16	15	15	H, M, P	quotient
racine	radix	MA	13	13	H, M	root
raison	ratio	MA	17	15	H, P	ratio
somme	summa	13	12	13	M, P	sum
soustraction	subtractio	15	15	15	H	subtraction
triangle	triangulus	15	13	13	P	triangle
unité	unitas	14	14		H, M	unity
zéro	zephirum	15	15	15	H, M	zero

Figure 20: The century of first recorded use of French mathematical terms used in the case-study works

Appendix 4: Hérigone's *Cursus mathematicus*, or *Cours mathématique*

The full title of Hérigone's single, bilingual, six-volume case-study work is the *Cursus mathematicus, nova, brevi, et clara methodo demonstratus, per notas reales et universales, citra usum cujuscunque idiomatis intellectu faciles*, or *Cours mathématique, demonstré d'une nouvelle, briefve, et claire methode, par notes reelles et universelles, qui peuvent estre entenduës facilement sans l'usage d'aucune langue* [Mathematics Course, Demonstrated by a Brief and Clear New Method, Using Real and Universal Symbols and Abbreviations That May Easily Be Understood without the Use of any Language]. Although Hérigone's work is bilingual, for the sake of convenience I generally refer to it by its abbreviated Latin names, the *Cursus mathematicus* or *Cursus*, unless I am specifically discussing the French version, which is referred to as the *Cours mathématique*, or *Cours*.

The *Cursus* contains a range of paratextual sections. Once I introduce them, I refer to them using summary descriptions: the 'ad lectorem', or 'au lecteur' in volume one is referred to as the 'address to the reader', the 'præfatio' and 'prefaces' in volumes two to five as 'the prefaces', the 'prolegomena' and 'prolegomenes' in volume one as the 'prolegomena', the 'errata corrigenda (in textu)' and 'les erreurs à corriger (au texte)' in each volume as the 'errata', the 'annotationes' and 'annotations' sections as the 'notes sections', the 'explicatio notarum' and 'explication des notes' as the '(explanatory) table of symbols and abbreviations', and the 'explicatio citationum' and 'explication des citations' as the '(explanatory) table of references'. I refer to the dedication to Bassompierre in volume one as the 'dedication' and the '(extraict du) privilege du roi' as the *privilège du roi* or *privilège*.

As can be seen in figure 21 below, the main text in each volume is paginated continuously from page 1. The only exception occurs in the second volume, where its two constituent books are paginated separately. The paratext in all six volumes is less straightforward. The paratext that precedes the main text is not paginated in any of the volumes. This is also true for all of the paratext that follows the main text in volume one and some of the paratext in volume two; in the other volumes, this paratext is paginated to follow on from the main text. I have paginated unpaginated paratext for ease of reference, using roman numerals, beginning with the title page in each volume as page i.

Section	Volume 1	Volume 2	Volume 3	Volume 4	Volume 5	Volume 6
Paratext before main text	Title and contents pages (pp. i–iv)	Title and contents page (pp. i–ii)	Title and contents page (pp. i–ii)	Title and contents page (pp. i–ii)	Title and contents page (pp. i–ii)	Title and contents page (pp. i–ii)
	Dedication (pp. v–viii)	---	---	---	---	---
	‘Ad Lectorem’ (pp. ix–xii)	‘Preface’ (pp. iii–vi)	‘Preface’ (pp. iii–v)	‘Preface’ (pp. iii–viii)	‘Preface’ (pp. iii–viii)	---
	‘Prolegomena’ (pp. xiii–xx)	Main contents of ‘Arithmetica Practica’ (p. vi)	---	---	---	---
	‘Explicatio notarum’ (pp. xx–xxviii)	‘Explicatio notarum’ (pp. vii–x)	‘Explicatio notarum’ (pp. v–x)	‘Explicatio notarum’ (p. ix)	‘Explicatio notarum’ (pp. ix–x)	‘Explicatio notarum’ (pp. iii–iv)
	---	‘Annotationes’ (pp. x–xii)	---	---	---	---
	---	‘Errata corrigenda’ (p. xiii–xiv)	---	---	‘Errata corrigenda’ (pp. xi–xiv)	---
	‘Explicatio citationum’ (pp. xxviii–xxxi)	---	‘Explicatio citationum’ (p. x)	---	---	---
	---	---	‘Errata corrigenda’ (p. xi)	‘Errata corrigenda’ (pp. x–xii)	---	---
	---	---	---	---	Propositions for *Optics* (pp. xiv–xv)	---
	---	---	‘Extraict du Privilege du Roy’ (p. xii)	---	‘Extraict du Privilege du Roy’ (p. xvi)	---

Main text	Euclid's *Elements* book 1 definitions (pp. xxxii–lx) and petitions (pp. lxi–lxxx); Euclid's *Elements* (pp. 1–800); Euclid's *Data* (pp. 801–89); five works by Apollonius Pergeus (pp. 890–934); Viète's *Angularium sectionum doctrina* (pp. 935–83)	'Arithmetica Practica' (pp. 1–162); contents of 'Algebra' (pp. xv–xvi); 'Algebra' (pp. 1–296)	'Trigonometriæ' (pp. 1–113); 'Geometriæ Practicæ' (pp. 114–78); 'De munitione' (pp. 179–231; 'De militia' (pp. 232–82); 'Mechanica' (pp. 283–329).	'De sphæra mundi' (pp. 1–155); 'Geographia' (pp. 156–399); and 'Histiodromia' (pp. 400–99)	'Optica' (pp. 1–86); 'Catoptrica' (pp. 87–125); 'Dioptrica' (pp. 126–89); 'Perspectiva' (pp.190–217); 'Theodosii Sphæricorum' (pp. 218–450); 'Theoricæ Planetarum' (pp. 451–681); 'Gnomonica' (pp. 682–802); 'Euclidis Musica' (pp. 802–56); 'Longitude' (pp. 857–82)	'Supplementum algebræ' (pp. 1–73); 'Isagoge de l'algebre' (pp. 74–98); 'De la perspective' (pp. 99–116), 'Brief traité de la theorie des planetes' (pp. 116–58) ; 'Introduction en la chronologie' (pp. 159–267)
Paratext after main text	---	'Annotationes' (p. xvii)	---	---	---	'Annotations' (pp. 268–86)
	'Errata corrigenda' (pp. lxxxi–lxxxiii)	'Errata corrigenda' (pp. xviii–xix)	---	---	---	'Erreurs à corriger' (pp. 287–88)
	'Privilege du Roy' (pp. lxxxiv–lxxxv)	'Extraict du Privilege du Roy' (p. xx)	---	'Extraict du Privilege du Roy' (p. 500)	---	'Annotations' (pp. 289–90)
	'Errata' (pp. lxxxvi–xci)	'Errata' (p. 297)	'Errata' (pp. 331–32)	'Errata' (pp. 501–02)	---	---
	'Annotationes' (pp. xcii–ci)	'Annotationes' (pp. 297–305, 308–28)	'Annotationes' (pp. 333–46)	'Annotationes' (pp. 502–04)	'Annotationes' (pp. 882–84)	---
	---	'Errata' (pp. 305–07)	---	---	'Errata' (p. 884)	---

Figure 21: The full structure of the Cursus mathematicus

Appendix 5: Mersenne's *Harmonie universelle* and *Harmonicorum libri*

Section A: The structure of the *Harmonie universelle*

The full title of the French work, published in 1637, is *Harmonie universelle, contenant la theorie et la pratique de la musique* [Universal Harmony, Containing the Theory and Practice of Music]. I refer to it throughout as the *Harmonie universelle*. In order to avoid confusion, I have used a facsimile of Mersenne's own annotated copy of the work, belonging to the Bibliothèque des Arts et Métiers in Paris and published in three volumes by the *Centre national de la recherche scientifique* [French National Centre for Scientific Research] (CNRS) in 1965. I have chosen to use this particular copy because, as explained in chapter 4, there are numerous versions of the text and the 1965 version is the standard edition, the one that 'it has become customary [for scholars] to rely on' (Meli 2004: 177).

As can be seen in figure 22 below, the *Harmonie universelle* is made up of nineteen books in four treatises, plus two additional works. The treatises are referred to in brief in chapter 4 as the *Traitez de la nature des sons*, *et des mouvements*, the *Traitez de la voix, et des chants*, the *Traitez des consonances, des dissonances, et de la composition* and the *Traité des instrumens*. The two additional works are Roberval's *Traité de mechanique*, which follows the *Traitez de la nature des sons*, *et des mouvements*, and Mersenne's *Nouvelles observations physiques et mathématiques*, which appears at the end of the *Harmonie universelle*, following the *Traité des instrumens*. The books that make up the four treatises and the two additional works are referred to by their full titles when they are first mentioned in the thesis and by abbreviated titles thereafter; their full titles can be found in figure 22, with translations.

The order presented by Guillo and mentioned in chapter 4 differs from the CNRS edition. He presents a two-volume 'édition "idéale"' ["perfect" version], based on a range of editions (2003: II, 297). He places all of the initial paratext, the three books of the *Traitez de la nature des sons*, *et des mouvements* and Roberval's treatise in his first volume, in the same order as the CNRS edition. He follows this with the paratext and the two books from the *Traitez de la voix, et des chants* from volume two of the CNRS edition. The main difference between the two versions arises at this point: Guillo completes his first volume with the paratext and books from the *Traité des instruments* from volume three of the CNRS edition. Volume two in Guillo’s version consists of the remainder of the material from the CNRS edition: the paratext and books in the *Traitez des consonances, des dissonances, et de la composition* from volume two of the CNRS edition, and the *Livre de l'utilité de l'harmonie* and the *Nouvelles observations* from the third volume. Although the changes make Guillo’s version seem very different, he has mainly retained the order of the CNRS edition, only switching the third and fourth treatises. While this reflects the order found in most extant copies, the CNRS edition more closely follows the order implicit in the *Harmonicorum libri*, where the books on instruments follow the rest of the books. It also follows the order given in the ‘Table des propositions’ in the CNRS edition (1965a: xvii–xlvi).

Figure 22 shows the full structure of the twenty-one books in the three volumes of the CNRS version of the *Harmonie universelle*. The first column in the table provides the volume and book number, the second column either the title of a book or treatise, the title of paratext, or a description of untitled paratext, and the third column details of pagination. The main text is fully paginated, with arabic numerals, all four treatises beginning at page 1. The fourth treatise, on musical instruments, is split in three: the first six books run continuously from page 1 to page 412, but the sixth and seventh books are paginated separately, beginning again at page 1. In addition, Roberval’s treatise at the end of volume 1, and Mersenne’s *Nouvelles observations*, at the end of volume 3, are also paginated separately, both starting at page 1. Pagination in the main text is inaccurate in a number of places, so I have added the number of pages in each book in the fourth column of the table and notes in the fifth column to help with understanding. The paratext is not generally paginated, so, for ease of reference, I have used lower case roman numerals to do so. Each group of pages begins at page i: the initial pages of the *Harmonie universelle*, and the paratext that precedes the four treatises, the *Livre sixiesme des orgues*, and Roberval’s *Traité de mechanique*.

HARMONIE UNIVERSELLE, CONTENANT LA THEORIE ET LA PRATIQUE DE LA MUSIQUE [UNIVERSAL HARMONY, CONTAINING THE THEORY AND PRACTICE OF MUSIC]				
VOLUME/BOOK NUMBER	**Title/description**	**Page numbers**	**No. of pages**	**Notes**
VOLUME 1	Title pages	i–iv	4	Full title, image, name of printer, date of publication; blank page, except for name of printer of musical notation; image of Orpheus with his lyre; blank page
	'Premiere preface generale au lecteur' [First General Preface to the Reader]	v–xvi	12	Page xvi also includes 'Extraict du privilege du roy' [Extract from *privilège du roi*] and 'Approbation des theologiens de l'ordre des Minimes' [Approval from the Theologians of the Order of the Minims]
	'Table des propositions des dix-neuf Livres de l'Harmonie Universelle' [Table of Propositions of the Nineteen Books of the *Harmonie Universelle*]	xvii–xlvi	30	The titles of all of the propositions in the *Harmonie universelle*, some reworded and renumbered from the main text, preceded by an introduction
	'Premier advertisssement', 'Second advertissement' [First and Second Notices]; 'Abregé de la musique speculative [Summary of Speculative Music]	xlvii–xlviii	2	Errata and a brief summary of the work
	'Table des XIX. livres de musique' [Table of the 19 Books on Music]	xlix–lvii	9	Subject index for all nineteen books, preceded by an introduction
	'Premiere observation' and 'Seconde observation' [First and Second Observations]	lviii–lx	3	Two preliminary observations about music
	TRAITEZ DE LA NATURE DES SONS, ET DES MOUVEMENTS DE TOUTES SORTES DE CORPS [TREATISE ON THE NATURE OF SOUNDS AND ON THE MOVEMENT OF ALL SORTS OF BODIES]			
	Title pages	i–ii	2	The second page is blank
	Dedication 'A tres-haut, tres-illustre, et tres-genereux Prince Monseigneur Louis de Valois Conte d'Alais, et Colonnel General de la Cavallerie Legere de France'	iii–vi	4	
	'Preface au Lecteur' and errata	vii–viii	2	

VOLUME 1 (cont.)	**TRAITEZ DE LA NATURE DES SONS, ET DES MOUVEMENTS DE TOUTES SORTES DE CORPS** (cont.)			
Livre premier [Book One]	'De la nature et des proprietez du son' [On the Nature and Properties of Sound]	1–84	84	
Livre second [Book Two]	'Des mouvements de toutes sortes de corps' [On the Movements of All Sorts of Bodies]	85–156	72	Pages 140–41 are numbered as pages 240–41
Livre troisiesme [Book Three]	'Du mouvement, de la tension, de la force, de la pesanteur, et des autres proprietez des chordes harmoniques, et des autres corps' [On Movement, Tension, Force, Gravity and the Other Properties of Harmonic Chords and Other Bodies]	157–228	72	There are errata and an 'advertissement' on page 228.
	Diagrams, 'Advertissement au lecteur' [Reader's Notice], errata	i–ii	2	All relate to Roberval's treaty that follows
	'Traité de mechanique: Des poids soustenus par des puissances sur les plans inclinez à l'horizon' [Treatise on Mechanics: On Weights Supported by Surfaces Inclined to the Horizontal]	1–36	36	'Par G. Pers. De Roberval Professeur Royal és Mathematiques au College de Maistre Gervais, et en la Chaire de Ramus au College Royal de France' [By Gilles Personne de Roberval, Royal Professor of Mathematics at the Gervais College and holder of the Ramus chair at the Collège Royal de France]
VOLUME 2	**TRAITEZ DE LA VOIX, ET DES CHANTS [TREATISE ON THE VOICE AND ON SONGS]**			
	Title pages	i–ii	2	The second page is blank
	Dedication to 'Monsieur Halle, Seigneur de Boucqueval, Conseiller du Roy, et Maistre des Contes'	iii–v	3	
	'Preface au lecteur' and errata	vi–viii	3	
Livre premier [Book One]	'De la voix, des parties qui servent à la former, de sa definition, de ses proprietez, et de l'oüye' [On the Voice, the Parts that Serve to Form It, Defining It, Its Properties, and Hearing]	1–88	88	Page 76 is numbered as page 74; page 81 is unnumbered
Livre second [Book Two]	'Des chants' [On Songs]	89–180	92	Pages 119–20 are numbered as pages 127–28, and pages 125–26 as pages 133–34

VOLUME 2 (cont.)	**TRAITEZ DES CONSONANCES, DES DISSONANCES, DES GENRES, DES MODES, ET DE LA COMPOSITION [TREATISE ON CONSONANCE, DISSONANCE, GENRES, MODES AND ON COMPOSITION]**			
	Title pages	i–ii	2	The second page is blank
	Dedication to 'Monsieur Nicolas Claude Fabry, Sieur de Peiresc et de Callas, Baron de Rians, Abbé et Seigneur de Guistres, et Conseiller du Roy en la Cour de Parlement d'Aix en Provence'	iii–vi	4	
	'Preface, et Advertissement au lecteur', and errata	vii–xii	6	
Livre premier [Book One]	'Des consonances' [On Consonance]	1–112	112	Page 85 is numbered as page 89
Livre second [Book Two]	'Des dissonances' [On Dissonance]	113–40	28	
Livre troisiesme [Book Three]	'Des genres, des especes, des systemes, et des modes de la musique' [On Musical Genres, Types, Systems and Modes]	141–96	58	Page 146 is numbered as page 144, and pages 176 and 178 as pages 180 and 182. An additional unnumbered sheet has been inserted between pages 164 and 165; it has a diagram on one side and is blank on the other.
Livre quatriesme [Book Four]	'De la composition de musique' [On Musical Composition]	197–282	76	Pages 202 and 217 are numbered as pages 182 and 219, while page numbers 221–30 are omitted entirely
Livre cinquiesme [Book Five]	'De la composition de musique' [On Musical Composition]	283–330	52	Pages 291–323 are numbered as pages 191–223, and pages 324–34 as pages 324–30, with four pages unnumbered, so that the next books starts at page 331
Livre sixiesme [Book Six]	'De l'art de bien chanter' [On the Art of Singing Well]	331–442	112	Pages 333–40 are numbered as pages 133–40, and pages 359–62 as a second set of pages 363–66; pages 440–42 include errata and approvals from the order of Minims in Latin and French

VOLUME 3	**TRAITÉ DES INSTRUMENS A CHORDES [TREATISE ON STRING INSTRUMENTS]**			
	Title pages	i–ii	2	The second page is blank
	Dedication to 'Monsieur de Refuge, Conseiller au Parlement'	iii–v	3	
	'Preface au lecteur', and errata	vi–viii	3	
Livre premier [Book One]	'Des instrumens a chordes' [On Stringed Instruments]	1–unnumbered (following 46)	52	The pages after page 41 are alternately unnumbered or are numbered pages 43–46
Livre second [Book Two]	'Des instruments a chordes' [On Stringed Instruments]	45–unnumbered (following 100)	72	First nine pages after page 92 are numbered 85–93; from page 93, rest are 94–100 or unnumbered
Livre troisiesme [Book Three]	'Des instrumens a chordes' [On Stringed Instruments]	101–76	76	The pages after page 164 are numbered 169–76 or are unnumbered, generally alternately
Livre quatriesme [Book Four]	'Des instrumens a chordes' [On Stringed Instruments]	177–228	52	
Livre cinquiesme [Book Five]	'Des instrumens a vent' [On Wind Instruments]	225–308	86	Includes one unnumbered hand-drawn page with blank reverse between pages 232–33
	Dedication to 'Monsieur Pascal cy devant President en la Cour des Aydes en Auvergne'	ix–x	2	
	'Preface au lecteur' and errata	xi–xii	2	
Livre sixiesme [Book Six]	'Des orgues' [On Organs]	309–412	110	Includes six pages of handwritten musical notation between pages 392–93 and a notice on page 412.
Livre septiesme [Book Seven]	'Des instrumens de percussion' [On Percussion Instruments]	1–72	79	Pages 1–72; two handwritten pages between pages 7 and 8; three pages of musical notation between pages 56 and 57; pages 61, 66, 67 are unnumbered.
	Errata	73–79	7	Errata and information relating to the whole work
Livre (huictiesme) [Book Eight]	'De l'utilité de l'harmonie, et des autres parties des mathematiques' [On the Usefulness of Harmony and the Other Parts of Mathematics]	1–68	68	Pages 64–68 include errata and notices for the whole work
	'Nouvelles observations physiques et mathematiques' [New Physical and Mathematical Observations]	1–28	39	Also includes two handwritten pages between pages 22 and 23, and, following page 28, one page with a drawing of an organ and seven handwritten pages

Figure 22: The full structure of the Harmonie universelle

Section B: The structure of the *Harmonicorum libri* and *Harmonicorum instrumentorum libri IV*

The Latin case-study work, the *Harmonicorum libri* [Books on Harmonics], was originally published in 1635 and 1636 under two titles: eight books were published as the *Harmonicorum libri* and four as the *Harmonicorum instrumentorum libri IV* [The Four Books on the Harmonics of Instruments]. All twelve books were reissued together in 1648 as the *Harmonicorum libri XII*. In chapter 4, I refer to all twelve books collectively as the *Harmonicorum libri* unless I need to distinguish between the two separate original works. The individual titles of the twelve books and their translations can be found in figure 23 below.

Figure 23 shows the full structure of the *Harmonicorum libri* and *Harmonicorum instrumentorum libri*. The first column of the table provides the volume and book number in the edition on the *Gallica* website (see bibliography). The second column gives either a description of pages of paratext without a title, the title of a section of paratext, or the title of a book. The third column provides page numbers. In both the *Harmonicorum libri* and *Harmonicorum instrumentorum libri IV*, the main text is paginated continuously from page 1. In contrast, none of the paratext, all of which precedes the main text, is numbered. Consequently, as with the *Harmonie universelle*, for ease of reference I have paginated it using roman numerals, beginning with the title pages of both separate works as page i. It should be noted that the pagination in the main text is inaccurate in a number of places. For purposes of clarity, I have added the number of pages in each book in the fourth column and notes in the fifth column to help with understanding the pagination.

	HARMONICORUM LIBRI			
Book number	**Title**	**Page no.**	**Pages**	**Notes**
	Title pages	i–ii	2	The second page is blank
	Dedication to Illustri Viro Henrico Ludovico Haberto Mommoro, Sacri Consistorii Comiti, et Libellorum Supplicum Magistro	iii–iv	2	
	‘Præfatio ad eundem’ [Preface to the Same]	v–xii	8	Contains four propositions, errata, a notice, extracts from the *privilège* and approval from the Minims
Liber primus [Book One]	‘De natura, et proprietatibus sonorum’ [On the Nature and Properties of Sounds]	1–9	8.5	
Liber secundus [Book Two]	‘De causis sonorum, seu de corporibus sonum producentibus’ [On the Causes of Sounds, or of Bodies that Produce Sound]	9–34	25.5	
Liber tertius [Book Three]	‘De fidibus, nervis et chordis, atque metallis, ex quibus fieri solent’ [On Strings, Wires and Chords, and also the Metals out of Which They are Generally Made]	35–49	15	Pages 43–46 are numbered as pages 51–54.
Liber quartus [Book Four]	‘De sonis consonis, seu consonantiis’ [On Consonant Sounds, or Consonance]	50–67	18	
Liber quintus [Book Five]	‘De musicæ dissonantiis, de rationibus, et proportionibus’ [On Dissonant Music, Ratios and Proportions]	68–88	21	
Liber sextus [Book Six]	‘De speciebus consonantiarum, deque modis, et generibus’ [On Types, Modes, and Genres of Consonance]	89–112	26	Two additional pages are included between pages 94 and 95: a diagram backed with blank page
Liber septimus [Book Seven]	‘De cantibus, seu cantilenis, earumq; numero, partibus, et speciebus’ [On Songs, or Refrains, and their Number, Parts and Types]	113–52, 52–57	50	Contains two sets of pages numbered 133–136, and the pages after 152 are numbered as 52–57
Liber octavus [Book Eight]	‘De compositione musica, de canendi methodo, et de voce’ [On Musical Composition, and the Voice]	161–84	24	There is no list of propositions preceding the book

	HARMONICORUM INSTRUMENTORUM LIBRI IV			
Book number	**Title**	**Page no.**	**Pages**	**Notes**
	Title pages	i–ii	2	The second page is blank
	Dedication to ‘Nobilissimo Viro Nicolao Claudio Fabry, Peirescii, Calasiiq; Domino, Riansii Baroni, ac Guistrii Domino et Abbati’, etc.	iii	1	
	‘Præfatio ad lectorem amicum’ [Preface to the Friendly Reader] and ‘Monitum amicum’ [Friendly Notice]	iv	1	
Liber primus [Book One]	‘De singulis instrumentis ΕΝΤΑΤΟΙΣ, seu ΕΓΧΟΡΔΟΙΣ, hoc est nervaceis, et fidicularibus’ [On Single ΕΝΤΑΤΟΙΣ, or ΕΓΧΟΡΔΟΙΣ, Instruments, Namely String and Wire Instruments]	1–72	76	Two sets of pages are numbered 21–24, one following the other
Liber secundus [Book Two]	‘De instrumentis pneumaticis’ [On Wind Instruments]	73–112	40	The page headings say ‘De instrumentis harmonicis’
Liber tertius [Book Three]	‘De organis, campanis, tympanis, ac cæteris instrumentis’ [On Organs, Bells, Drums, and other Instruments]	113–144	32	
Liber quartus [Book Four]	‘De campanis, et aliis instrumentis, seu percussionis, ut tympanis, cymbalis etc’ [On Bells and Other Instruments, or On Percussion, Namely Drums, Cymbals, etc]	145–168	24	Pages 148–149 numbered as second pages 146–47; page 167 is numbered as a second page 165

Figure 23: The full structure of the Harmonicorum libri

Section C: Comparing the structures of the *Livre des chants* and the *Liber de cantibus*

Figure 24 shows the approximate correspondence between the propositions in the two books. A simplified version of the left-hand table can be found in section 4.3 (figure 9) in a comparison of the structure of the books.

Livre des chants	***Liber de cantibus***
Proposition number	**Proposition number**
I	II
II	
III	I
IV	
V	
VI	
VII	
VIII	III
IX	VI, VII
X	XIII
XI	IX, X, XI
XII	XIV
XIII	
XIV	
XV	
XVI	XII, X
XVII	XIII
XVIII	
XIX	XV
XX	
XXI	IV
XXII	
XXIII	XIX
XXIV	
XXV	
XXVI	
XXVII	
No equivalent	V, VIII, XVI–XVIII

Liber de cantibus	***Livre des Chants***
Proposition number	**Proposition number**
I	III
II	I
III	VIII
IV	XXI
V	
VI	IX
VII	
VIII	
IX	XI
X	XVI, XI
XI	XI
XII	XVI
XIII	X, XVII
XIV	XII, XIII
XV	XIX
XVI	
XVII	
XVIII	
XIX	XXIII–XXV
No equivalent	II, IV–VII, XIV–XV, XVIII, XX, XXII, XXVI–XXVII

Figure 24: Correspondence between the propositions in the Livre des chants *and* Liber de cantibus

Appendix 6: Pascal's treatises on the Arithmetic Triangle

Jean Mesnard has identified two sets of treatises written by Pascal on the subject of the Arithmetic Triangle. The first was written in 1654, printed wholly in Latin, but never published as a separate collection. The second collection was also printed in 1654, but was not distributed until 1665, three years after Pascal's death, under the title *Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere*. It contains French treatises, some of which are new to the second collection and some rewritten versions of Latin treatises from the first collection, along with other original Latin treatises. The second collection is referred to in this thesis by its abbreviated modern title, the *Traité du triangle arithmétique, avec quelques autres petits traités*, to avoid confusion with its principal treatise, the *Traité du triangle arithmétique*.

The Latin and French treatises in the two collections, with their full and abbreviated titles (as used in chapter 5), are set out in figures 25 and 26 below.

Treatise title	**English translation**	**Abbreviated title**
Triangulus arithmeticus	The Arithmetic Triangle	*Triangulus arithmeticus*
Numeri figurati, seu ordines numerici	Figurate Numbers, or Number Sequences	*Numeri figurati*
De numericis ordinibus tractatus	Treatise on Number Sequences	*De numericis ordinibus*
De numerorum continuorum productis, seu, de numeris qui producuntur ex multiplicatione numerorum serie naturali procedentium	On the Products of Continuous Numbers, or, on the Numbers Obtained by Multiplying Successive Numbers in a Natural Sequence	*De numerorum continuorum*
Numericarum potestatum generalis resolutio	General Solutions to Numerical Powers	*Numericarum potestatum*
Combinationes	Combinations	*Combinationes*
Potestatum numericarum summa	Summing Numerical Powers	*Potestatum numericarum summa*
De numeris multiplicibus, ex sola caracterum numericorum additione agnoscendis	Recognising Multiples Simply by Adding their Digits	*De numeris multiplicibus*

Figure 25: The first collection of treatises

Treatise title	**English translation**	**Abbreviated title**
Traité du triangle arithmétique	Treatise on the Arithmetic Triangle	*Traité du triangle arithmétique*
Divers usages du triangle arithmétique, dont le générateur est l'unité	Various Uses of the Arithmetic Triangle, with Generator Equal to 1	*Divers usages*
Usage du triangle arithmétique pour les ordres numériques	Use of the Arithmetic Triangle for Number Sequences	*Usage pour les ordres numériques*
Usage du triangle arithmétique pour les combinaisons	Use of the Arithmetic Triangle for Combinations	*Usage pour les combinaisons*
Usage du triangle arithmétique, pour déterminer les partis qu'on doit faire entre deux joueurs qui jouent en plusieurs parties	Use of the Arithmetic Triangle to Calculate the Shares to be Made between Two Players Who Play a Number of Games	*Usage pour les partis*
Usage du triangle arithmétique pour trouver les puissances des binômes et apotomes	Use of the Arithmetic Triangle to Find the Powers of Binomials and Apotomes	*Usage pour les binômes et apotomes*
Traité des ordres numériques	Treatise on Number Sequences	*Traité des ordres numériques*

Figure 26: The French treatises in the second collection

The *Traité du triangle arithmétique, avec quelques autres petits traités* is made up of most of the original Latin treatises and the new French treatises, plus six pages of paratext before the first treatise. The book was published as a single work in four parts, each paginated continuously from page 1 and preceded by the unnumbered paratext. For ease of reference I have paginated the paratext using roman numerals, beginning with the title page as page i. Figure 27 below shows the full composition of the second, published collection of mixed French and Latin of treatises, including treatise and page numbers.

Treatise number	Title or section name	Pages
	Title page and blank page	i–ii
	‘Avertissement’ [Notice]	iii
	‘Table des traitez contenus dans ce Recueil’ [Table of the Treatises Contained in this Collection]	iv
	Diagram of ‘Triangle Arithmetique’	v–vi
I	*Traité du triangle arithmétique* and unnumbered blank page	1–11
II	*Divers usages.* *Usage pour les ordres numériques* *Usage pour les combinaisons*	1 2–3 4–8
III	*Usage pour les partis*	1–13
IV	*Usage pour les binômes et apotomes*	14–16
V	*Traité des ordres numériques*	1–6
VI	*De numericis ordinibus*	7–12
VII	*De numerorum continuorum*	13–17
VIII	*Numericarum potestatum*	18–21
IX	*Combinationes*	22–33
X	*Potestatum numericarum summa*	34–41
XI	*De numeris multiplicibus*	42–48

Figure 27: The full composition of the Traité du triangle arithmétique, avec quelques autres petits traités sur la même matière

Bibliography

About, Pierre-José, and Boy, Michel. 1983. *La Correspondance de Blaise Pascal et de Pierre de Fermat: La Géométrie du hasard, ou, Le Début du calcul des probabilités*, Les Cahiers de Fontenay no. 32 (Fontenay-aux-Roses: ENS)

Adamson, Donald. 1995. *Blaise Pascal: Mathematician, Physicist and Thinker about God* (Basingstoke: Macmillan; New York: St Martin's Press)

Andersen, Kristi. 2007. *The Geometry of an Art: The History of the Mathematical Theory of Perspective from Alberti to Monge* (New York: Springer)

Anselmi, Simona. 2012. *On Self-Translation: An Exploration in Self-Translators' Teloi and Strategies* (Milan: Edizioni Universitarie di Lettere Economia Diritto)

Apollonius. 1990. *Apollonius's Conics Books V to VII: The Arabic Translation of the Lost Greek Original in the Version of the Banū Mūsā*, 2 vols, ed. and trans. by Gerald J. Toomer (New York: Springer)

Aquinas, St. Thomas. 1995. *Commentary on Aristotle's Metaphysics*, trans. and intr. by John P. Rowan (Notre Dame, IN: Dumb Ox)

Aristotle. 1960. *Posterior Analytics and Topics*, trans. by Hugh Tredinnick and E. S. Forster (Cambridge, MA: Harvard University Press)

Arnauld, Antoine, and Pierre Nicole. 1664. *La Logique, ou L'Art de penser*, 2nd edn (Paris: Savreux)

Assayag, Gerard, Hans Georg Feichtinger and Jose Francisco Rodrigues (eds). 2002. *Mathematics and Music: A Diderot Mathematical Forum* (Berlin: Springer)

Babbi, Anna Maria. 2011. 'L'Auto-traduction', in *Translations médiévales: Cinq siècles de traductions en français au Moyen Âge (XIe–XVe siècles): Étude et répertoire*, 3 vols, ed. by Claudio Galderisi (Turnhout: Brepols), vol. 1, pp. 383–95

Bachet de Méziriac, Claude-Gaspar. 1998. *De la traduction*, intr. by Michel Ballard (Arras: Artois Presses Université; Ottawa: Presses de l'Université d'Ottawa)

Bacon, Francis. 2011a. *The Works of Francis Bacon*, ed. by James Spedding, Robert Leslie Ellis and Douglas Denon Heath, 14 vols (Cambridge: Cambridge University Press)

Bacon, Francis. 2011b. 'To the Prince', in *The Works of Francis Bacon*, ed. by James Spedding, Robert Leslie Ellis and Douglas Denon Heath, 14 vols (Cambridge: Cambridge University Press), vol. 14, pp. 436–37

Bailhache, Patrice. 1994. 'L'Harmonie universelle: La Musique entre les mathématiques, la physique, la métaphysique et la religion', *Les Études philosophiques*, 1/2: 13–24

Baker, Mona (ed.). 1998. *Routledge Encyclopedia of Translation Studies* (London: Routledge)

Baker, Mona, and Gabriela Saldanha (eds). 2009. *Routledge Encyclopedia of Translation Studies*, 2nd edn (London: Routledge)

—— 2019. *Routledge Encyclopedia of Translation Studies*, 3rd edn (London: Routledge)

Ballard, Michel. 1998. ‘Introduction’, in *De la traduction*, by Claude-Gaspar Bachet de Méziriac (Arras: Artois Presses Université; Ottawa: Presses de l’Université d’Ottawa), pp. ix–xlvi

—— 2007. *De Cicéron à Benjamin: Traducteurs, traductions, réflexions*, 2nd edn (Villeneuve d’Ascq: Presses Universitaires du Septentrion)

Balliu, Christian. 2001. ‘Les traducteurs: Ces médecins légistes du texte’, *Meta*, 46(1): 92–102

Barbin, Évelyne, 1988. ‘La Démonstration mathématique: Significations épistémologiques et questions didactiques’, *Publications de l’Institut de recherche mathématique de Rennes*, 5: 1–34

Barker, John C. 1970. ‘The Royal Society and “The Ingenious Monsieur Pascal”’, *Historical Papers*, 5(1): 158–70

Barnard, John, D. F. McKenzie and Maureen Bell (eds). 2014. *The Cambridge History of the Book in Britain,* vol. 4, *1557–1695* (Cambridge: Cambridge University Press)

Bassnett, Susan. 2013a. ‘Rejoinder’, *Orbis Litterarum,* 68(3): 282–89

—— 2013b. ‘The Self-Translator as Rewriter’, in *Self-Translation: Brokering Originality in Hybrid Culture*, ed. by Anthony Cordingley (London: Bloomsbury), pp.13–25

—— 2014. *Translation* (London: Routledge)

Bastin, Georges L., and Paul F. Bandia (eds). 2006. *Charting the Future of Translation History* (Ottawa: University of Ottawa Press)

Batchelor, Kathryn. 2018. *Translation and Paratexts* (London: Routledge)

Bavington, Peter. 2012. ‘Reconstructing Mersenne’s Clavichord’, in *De Clavicordio X: Proceedings of the X International Clavichord Symposium, Magnano, 6–10 September 2011*, ed. by Bernard Brauchli, Alberto Galazzo, and Judith Wardman (Magnano: Musica Antica a Magnano), pp. 13–35

Beaugrand, Jean. 1946. ‘Lettre à Mersenne, 20 février 1632’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 3, pp. 254–56

Beaulieu, Armand. 1989. ‘Un moine passionné de musique, de sciences et d’amitié: Marin Mersenne’, *XVIIe siècle,* 41: 167–93

—— 1995. *Mersenne, le Grand Minime* (Brussels: Fondation Nicolas-Claude Fabri de Peiresc)

Beauzée, Nicolas. 1765. ‘Langues’, in *Encyclopédie, ou Dictionnaire raisonné des sciences, des arts et des métiers*, ed. by Denis Diderot and Jean le Rond d’Alembert, 17 vols (Paris: Briasson, David, Le Breton and Durand), vol. 9, pp. 245–72

Beeby, Allison, Doris Ensinger and Marisa Presas (eds). 2000. *Investigating Translation: Selected Papers from the 4th International Congress on Translation, Barcelona, 1988* (Amsterdam: Benjamins)

Beer, Jeanette (ed.). 1989. *Medieval Translators and their Craft* (Kalamazoo: Western Michigan University)

Bell, Maureen. 2002. 'Mise-en-page, Illustration, Expressive Form', in *The Cambridge History of the Book in Britain,* 7 vols (Cambridge: Cambridge University Press), vol. 4, *1557–1695*, ed. by John Barnard, D. F. McKenzie and Maureen Bell, pp. 632–62

Bellos, Alex. 2020. *Alex's Adventures in Numberland*, 2nd edn (London: Bloomsbury)

Benton, Megan L. 2007. 'The Book as Art', in *A Companion to the History of the Book*, ed. by Simon Eliot and Jonathan Rose (Oxford: Blackwell), pp. 493–507

Berkvens-Stevelinck, Christiane, Hans Bots, and Jens Häseler (eds). 2005. *Les grands intermédiaires culturels de la République des Lettres: Études de réseaux de correspondances du XVIe au XVIIIe siècles* (Paris: Champion)

Berman, Antoine. 1984. *L'Épreuve de l'étranger: Culture et traduction dans l'Allemagne romantique* (Paris: Gallimard)

Bermann, Sandra, and Catherine Porter (eds). 2014. *A Companion to Translation Studies* (Chichester: Wiley Blackwell)

Bernard, Alain, and Christine Proust (eds). 2014. *Scientific Sources and Teaching Contexts Throughout History: Problems and Perspectives* (Dordrecht: Springer)

Bernoulli, Jakob. 1795. 'The Doctrine of Permutations and Combinations, Being an Essential and Fundamental Part of the Doctrine of Chances', trans. by Francis Maseres, in *Mr. James Bernoulli's Doctrine of Permutations and Combinations, and Some Other Useful Mathematical Tracts*, ed. by Francis Maseres (London: White and White), pp. 1–213

Bernstein, Peter L. 1996. *Against the Gods: The Remarkable Story of Risk* (Chichester: Wiley)

Bertato, Fabio M. 2018. 'Attempts to Formalize as Syllogisms the Propositions of the *Elements* of Euclid Made by Herlinus, Dasypodius, Clavius and Hérigone', in *(Un-)Certainty and (In-)Exactness: Proceedings of the 1st CLE Colloquium for Philosophy and Formal Sciences*, ed. by Fabio Bertato and Gianfranco Basti (Ariccia: Aracne), pp. 109–39

Bertato, Fabio, and Gianfranco Basti (eds). 2018. *(Un-)Certainty and (In-) Exactness: Proceedings of the 1st CLE Colloquium for Philosophy and Formal Sciences* (Ariccia: Aracne)

Bertrand, Olivier. 2015. 'Le legs du Moyen Âge', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 1: *XVe et XVIe siècles*, ed. by Véronique Duché, pp. 49–126

Bethencourt, Francisco, and Florike Egmond (eds). 2007a. *Cultural Exchange in Early Modern Europe*, 4 vols (Cambridge: Cambridge University Press), vol. 3: *Correspondence and Cultural Exchange in Europe, 1400–1700*

—— 2007b. 'Introduction', in *Cultural Exchange in Early Modern Europe*, 4 vols (Cambridge: Cambridge University Press), vol. 3: *Correspondence and*

Cultural Exchange in Europe, 1400–1700, ed. by Francisco Bethencourt and Florike Egmond (Cambridge: Cambridge University Press), pp. 1–30

Bianchi, Eric. 2015. ‘Bad Latin, Bad Manners: Giovanni Battista Doni, Marin Mersenne, and Literary Style in Seventeenth-Century Music Theory’, *Music and Letters*, 96(2): 167–84

Bistué, Belén. 2013. *Collaborative Translation and Multi-Version Texts in Early Modern Europe* (Farnham: Ashgate)

Blair, Ann. 1999. ‘Natural Philosophy and the “New Science”’, in *The Cambridge History of Literary Criticism*, vol. 3, *The Renaissance*, ed. by Glyn P. Norton (Cambridge: Cambridge University Press), pp. 449–57

—— 2000. ‘La Persistance du latin comme langue de science à la fin de la renaissance’, in *Sciences et langues en Europe*, ed. by Roger Chartier and Pietro Corsi (Luxembourg: Office for Official Publications of the European Communities), pp. 19–39

—— 2010. *Too Much to Know: Managing Scholarly Information before the Modern Age* (New Haven: Yale University Press)

—— 2013. ‘Revisiting Renaissance Encyclopaedism’, in *Encyclopaedism from Antiquity to the Renaissance*, ed. by Jason König and Greg Woolf (Cambridge: Cambridge University Press), pp. 379–97

—— 2014a. ‘Descartes, René’, in *Brill’s Encyclopaedia of the Neo-Latin World*, 2 vols, ed. by Philip Ford, Jan Bloemendal and Charles Fantazzi (Leiden: Brill), vol. 2, pp. 956–58

—— 2014b. *Hidden Hands: Amanuenses and Authorship in Early Modern Europe*, The University of Pennsylvania Libraries A.S.W. Rosenbach Lectures in Bibliography for 2014, <https://repository.upenn.edu/rosenbach/8/> [accessed 14 July 2021]

—— 2014c. ‘Hidden Helpers’, in *Hidden Hands: Amanuenses and Authorship in Early Modern Europe*, The University of Pennsylvania Libraries A.S.W. Rosenbach Lectures in Bibliography for 2014

—— 2014d. ‘Hand and Minds at Work’, in *Hidden Hands: Amanuenses and Authorship in Early Modern Europe*, The University of Pennsylvania Libraries A.S.W. Rosenbach Lectures in Bibliography for 2014

Bleijenbergh, Inge. 2010. ‘Case Selection’, in *Encyclopedia of Case Study Research*, 2 vols, ed. by Albert J. Mills, Gabrielle Durepos and Elden Wiebe (Los Angeles: Sage), vol. 1, pp. 61–63

Bloemendal, Jan (ed.). 2015a. *Bilingual Europe: Latin and Vernacular Cultures, Examples of Bilingualism and Multilingualism c. 1300–1800* (Leiden: Brill)

—— 2015b. ‘Introduction: Bilingualism, Multilingualism and the Formation of Europe’, in *Bilingual Europe: Latin and Vernacular Cultures, Examples of Bilingualism and Multilingualism c. 1300–1800*, ed. by Jan Bloemendal (Leiden: Brill), pp.1–14

Blumenfeld-Kosinski, Renate, Luise von Flotow and Daniel Russell (eds). 2001. *The Politics of Translation in the Middle Ages and the Renaissance* (Ottawa: University of Ottawa Press)

Boardman, John, Jasper Griffin and Oswyn Murray. 1986. *The Oxford History of the Classical World* (London: Guild Publishing)
Boas, Marie. 1962. *The Scientific Renaissance, 1450–1630* (London: Collins)
Boase-Beier, Jean, Lina Fisher and Hiroko Furukawa (eds). 2018a. *The Palgrave Handbook of Literary Translation* (Cham: Palgrave Macmillan)
—— 2018b. 'Introduction', in *The Palgrave Handbook of Literary Translation*, ed. by Jean Boase-Beier, Lina Fisher, and Hiroko Furukawa (Cham: Palgrave Macmillan), pp. 1–18
Boisseau, Maryvonne (ed.). 2007. *De la traduction comme commentaire au commentaire de traduction* (Paris: Presses Sorbonne Nouvelle)
Bolduc, Michelle. 2006. *The Medieval Poetics of Contraries* (Gainesville: University Press of Florida)
—— 2020. *Translation and the Rediscovery of Rhetoric* (Toronto: Pontifical Institute of Mediaeval Studies)
Bonaventure, St. 1882a. *Opera omnia: Commentaria sententiarum Magistri Petri Lombardi*, 4 vols (Florence: Quaracchi)
—— 1882b. 'Procœmium', in *Opera omnia: Commentaria sententiarum Magistri Petri Lombardi,* by St. Bonaventure, 4 vols (Florence: Quaracchi), vol. 1, pp. 1–15
Bos, H. J. M. 1981. 'Huygens, Christiaan', in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 6, pp. 597–613
Bosmans, Henri. 1906. 'Une note historique sur le triangle arithmétique de Pascal', *Annales de la société scientifique de Bruxelles,* 31: 65–71
—— 1923. 'Pascal et son Traité du triangle arithmétique', *Mathesis,* 37: 455–64
—— 1924. 'Sur l'œuvre mathématique de Blaise Pascal', *Mathesis*, 38: *Supplément* 1–59
Bots, Hans. 2005. 'Marin Mersenne, "secrétaire général" de la République des Lettres (1620–1648)', in *Les grands intermédiaires culturels de la République des Lettres: Études de réseaux de correspondances du XVIe au XVIIIe siècles*, ed. by Christiane Berkvens-Stevelinck, Hans Bots, and Jens Häseler (Paris: Champion), pp. 165–81
Boyden, Michael, and Liesbeth De Bleeker. 2013. 'Introduction', *Orbis Litterarum,* 68(3): 177–87
Boyden, Michael, and Lieve Jooken. 2013. 'A Privileged Voice? J. Hector St. John de Crèvecœur's "History of Andrew, the Hebridean" in French and Dutch Translation', *Orbis Litterarum*, 68(3): 222–50
Boyer, Carl B. 1950. 'Cardan and the Pascal Triangle', *The American Mathematical Monthly*, 57(6): 387–90.
Boyle, Deborah. 1999. 'Descartes' Natural Light Reconsidered', *Journal of the History of Philosophy*, 37(4): 601–12
Brauchli, Bernard, Alberto Galazzo, and Judith Wardman (eds). 2012. *De Clavicordio X: Proceedings of the X International Clavichord Symposium, Magnano, 6–10 September 2011* (Magnano: Musica Antica a Magnano)
Bret, Patrice, and Ellen Moerman. 2014. 'Sciences et arts', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII*^{e} *et*

XVIIIe siècles (1610–1815), ed. by Yves Chevrel, Annie Cointre and Yen-Maï Tran-Gervat, pp. 595–722

Britannica, The Editors of Encyclopædia. 2020. 'François de Bassompierre', in *Encyclopaedia Britannica* <https://www.britannica.com/biography/Francois-de-Bassompierre> [accessed 8 March 2021]

—— 2021. 'Gabriel Naudé', in *Encyclopaedia Britannica* <https://www.britannica.com/biography/Gabriel-Naude> [accessed 6 August 2021]

Brockliss, Laurence W.B. 1987. *French Higher Education in the Seventeenth and Eighteenth Centuries: A Cultural History* (Oxford: Clarendon Press)

Brotton, Jerry. 2006. *The Renaissance: A Very Short Introduction* (Oxford: Oxford University Press)

Brunot, Ferdinand. 1922. *Histoire de la langue française des origines à 1900*, 13 vols, 2nd edn (Paris: Colin), vol. 2: *Le Seizième siècle*

Brunschvicg, Léon and Pierre Boutroux. 1908. 'Introduction: Traité du triangle arithmétique avec quelques autres petits traitez sur la mesme matière', in *Œuvres de Blaise Pascal*, ed. by Léon Brunschvicg, Pierre Boutroux and Félix Gazier, 14 vols (Paris: Hachette), vol. 3, pp. 435–44

Brunschvicg, Léon, Pierre Boutroux and Félix Gazier. 1914. 'Introduction: De l'Esprit géométrique', in *Œuvres de Blaise Pascal*, ed. by Léon Brunschvicg, Pierre Boutroux and Félix Gazier, 14 vols (Paris: Hachette), vol. 9, pp. 231–39

Budick, Stanford, and Wolfgang Iser (eds). 1996. *The Translatability of Cultures: Figurations of the Space Between* (Stanford: Stanford University Press)

Bueno García, Antonio, David Pérez Blázquez and Elena Serrano Bertos (eds). 2016. *Dominicos 800 años: Labor intelectual, lingüística y cultural* (Salamanca: San Esteban)

Bulmer-Thomas, Ivor. 1981a. 'Euclid', in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 4, pp. 414–37

—— 1981b. 'Hypsicles of Alexandria', in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 6, pp. 616–17

—— 1981c. 'Isidorus of Miletus', in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 7, pp. 28–30

Buridant, Claude. 2011. 'Esquisse d'une traductologie au Moyen Âge', in *Translations médiévales: Cinq siècles de traductions en français au Moyen Âge (XIe–XVe siècles): Étude et répertoire*, 3 vols, ed. by Claudio Galderisi (Turnhout: Brepols), vol. 1, pp. 325–91

Burke, Martin J., and Melvin Richter (eds). 2012. *Why Concepts Matter: Translating Social and Political Thought* (Leiden: Brill)

Burke, Peter. 2004. *Languages and Communities in Early Modern Europe* (Cambridge: Cambridge University Press)

—— 2007a. 'Cultures of Translation in Early Modern Europe', in *Cultural Translation in Early Modern Europe*, ed. by Peter Burke and R. Po-chia Hsia (Cambridge: Cambridge University Press), pp. 7–38

—— 2007b. ‘Translations into Latin in Early Modern Europe’, in *Cultural Translation in Early Modern Europe,* ed. by Peter Burke and R. Po-chia Hsia (Cambridge: Cambridge University Press), pp. 65–80

Burke, Peter, and R. Po-chia Hsia (eds). 2007. *Cultural Translation in Early Modern Europe* (Cambridge: Cambridge University Press)

Burnett, Charles. 2001. ‘The Coherence of the Arabic–Latin Translation Program in Toledo in the Twelfth Century’, *Science in Context*, 14(1/2): 249–88

Burton, Gideon O. 2016. *Silva Rhetoricæ: The Forest of Rhetoric* (Provo: Brigham Young University) <http://rhetoric.byu.edu/> [accessed 26 March 2021]

Busard, H. L. L. 1981. ‘Clavius, Christoph’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 3, pp. 311–12

Bussey, W.H. 1917. ‘The Origin of Mathematical Induction’, *The American Mathematical Monthly*, 24(5): 199–207

Buzon, Frédéric de. 1994. ‘Harmonie et métaphysique: Mersenne face à Kepler’, *Les Études philosophiques*, 1/2: 119–28

Caiazzo, Irene. 2019. ‘Teaching the *Quadrivium* in the Twelfth-Century Schools’, in *A Companion to Twelfth-Century Schools*, ed. by Cédric Giraud (Leiden: Brill), pp. 180–202

Cajori, Florian. 1993. *A History of Mathematical Notations* (New York: Dover)

Calinger, Ronald (ed.). 1996. *Vita Mathematica: Historical Research and Integration with Teaching* (Washington: Mathematical Association of America)

Campi, Emidio, Simone De Angelis, Anja-Silvia Goeing, and Anthony T. Grafton (eds). 2008. *Scholarly Knowledge: Textbooks in Early Modern Europe* (Geneva: Droz)

Cappelli, Adriano. 1982. *The Elements of Abbreviation in Medieval Latin Paleography*, trans. by David Heimann and Richard Kay (Lawrence: University of Kansas Libraries)

Casanova, Pascale. 2008. *La République mondiale des lettres*, 2nd edn (Paris: Éditions du Seuil)

Cauty, André. 1998. ‘Pourquoi faire simple …’, *Bulletin de l’APMEP*, 417: 464–74

Centre National de Ressources Textuelles et Lexicales (CNRTL). 2012. *Etymologie* <https://www.cnrtl.fr/etymologie/> [accessed 23 February 2021]

Chartier, Roger, and Pietro Corsi (eds). 2000. *Sciences et langues en Europe* (Luxembourg: Office for Official Publications of the European Communities)

Chartier, Roger, Dominique Julia and Marie-Madeleine Compère. 1976. *L’Éducation en France du XVIe au XVIIIe siècle* (Paris: Société d’Edition d’Enseignement Supérieur)

Chenoweth, Katie. 2016. ‘Montaigne on Language’, in *The Oxford Handbook of Montaigne*, ed. by Philippe Desan (Oxford: Oxford University Press), pp. 367–83

Chevalier, Jacques. 1954. ‘*De l’esprit géométrique* et *De l’art de persuader*’, in

Œuvres complètes, by Blaise Pascal, ed. and annot. by Jacques Chevalier (Paris: Gallimard), p. 575

Chevrel, Yves, Annie Cointre and Yen-Maï Tran-Gervat (eds). 2014a. *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII^e^ et XVIII^e^ siècles (1610–1815)*

—— 2014b. 'Introduction', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII^e^ et XVIII^e^ siècles (1610–1815)*, ed. by Yves Chevrel, Annie Cointre and Yen-Maï Tran-Gervat, pp. 33–53

—— 2014c. 'Bilan', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII^e^ et XVIII^e^ siècles (1610–1815)*, ed. by Yves Chevrel, Annie Cointre and Yen-Maï Tran-Gervat, pp. 1283–1302

Cicero, Marcus Tullius. 1942. *De Oratore, Books I–II*, ed. by Jeffrey Henderson, trans. by E.W. Sutton, intr. by H. Rackham (Cambridge, MA: Harvard University Press)

Cifoletti, Giovanna. 1992. *Mathematics and Rhetoric: Jacques Peletier, Guillaume Gosselin and the Making of the French Algebraic Tradition* (unpublished PhD dissertation, Princeton University) [pages unnumbered]

—— 2000. 'Du français au latin: L'*Algèbre* de Jacques Peletier et ses projets pour une nouvelle langue des sciences', in *Sciences et langues en Europe*, ed. by Roger Chartier and Pietro Corsi (Luxembourg: Office for Official Publications of the European Communities), pp. 91–101

—— 2014. 'Mathematical Progress or Mathematical Teaching? Bilingualism and Printing in European Renaissance Mathematics', in *Scientific Sources and Teaching Contexts Throughout History: Problems and Perspectives*, ed. by Alain Bernard and Christine Proust (Dordrecht: Springer), pp. 187–214

Clagett, Marshall. 1981. 'Archimedes', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 1, pp. 213–31

Clapham, Christopher, and James Nicholson. 2014. *The Concise Oxford Dictionary of Mathematics*, 5th edn (Oxford: Oxford University Press)

Clarke, Desmond M. 2003. 'Pascal's Philosophy of Science', in *The Cambridge Companion to Pascal*, ed. by Nicholas Hammond (Cambridge: Cambridge University Press), pp. 102–21

Classe, Olive (ed.). 2000. *Encyclopedia of Literary Translation into English*, 2 vols (London: Fitzroy Dearborn)

Clavius, Christoph. 1570. *In Sphærum Joannis de Sacro Bosco Commentarius* (Rome: Helianum)

Clerté, Bernard. 1986. 'Commentaire: L'Esprit de la géométrie', in *L'Esprit de la géométrie, De l'art de persuader: Textes et commentaires*, by Blaise Pascal, ed. by Bernard Clerté and Martine Lhoste-Navarre (Paris: Bordas), pp. 55–125

Cohen, H. Floris. 1984. *Quantifying Music: The Science of Music at the First Stage of the Scientific Revolution, 1580–1650* (Dordrecht: Reidel)
—— 2010. *How Modern Science Came into the World: Four Civilizations, One 17th-Century Breakthrough* (Amsterdam: Amsterdam University Press)
—— 2015. ‘From *Philosophia Naturalis* to Science, from Latin to the Vernacular’, in *Bilingual Europe: Latin and Vernacular Cultures, Examples of Bilingualism and Multilingualism c. 1300–1800*, ed. by Jan Bloemendal (Leiden: Brill), pp. 144–60
—— 2016. 'The Mathematization of Nature', in *Historiography of Mathematics in the 19th and 20th Centuries*, ed. by Volker R. Remmert, Martina R. Schneider and Henrik Kragh Sørensen (Cham: Birkhäuser), pp. 143–60
Colbus, Jean-Claude, and Brigitte Hébert (eds). 2006. *Les outils de la connaissance: Enseignement et formation intellectuelle en Europe entre 1453 et 1715* (Saint-Étienne: Publications de l’Université de Saint-Étienne)
Coldiron, Anne E. B. 2015. *Printers without Borders: Translation and Textuality in the Renaissance* (Cambridge : Cambridge University Press)
Colombat, Bernard. 1992. ‘Les XVIIe et XVIIIe siècles français face à la pédagogie du latin’, *Vita Latina*, 126: 30–43
Consortium of European Research Libraries (CERL). 2011. *Heritage of the Printed Book (HPB) database* <https://www.cerl.org/resources/hpb/main> [accessed 16 August 2021]
Cooper, Michael, and Michael Hunter (eds). 2006. *Robert Hooke: Tercentennial Studies* (Aldershot: Ashgate)
Cordingley, Anthony (ed.). 2013a. *Self-Translation: Brokering Originality in Hybrid Culture* (London: Bloomsbury)
—— 2013b. ‘Introduction’, in *Self-Translation: Brokering Originality in Hybrid Culture*, ed. by Anthony Cordingley (London: Bloomsbury), pp. 1–10
—— 2018. ‘Self-translation’, in *The Routledge Handbook of Literary Translation*, ed. by Kelly Washbourne and Ben Van Wyke (Abingdon: Routledge), pp. 352–68
Costabel, Pierre. 1981a. ‘Debeaune, Florimond’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 3, pp. 614–16
—— 1981b. ‘Morin, Jean-Baptiste’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 9, pp. 527–28
Cotgrave, Randle. 1611. *A Dictionarie of the French and English Tongues* (London: Islip)
Coumet, Ernest. 1972. ‘Mersenne: Dénombrements, répertoires, numérotations de permutations’, *Mathématiques et sciences humaines*, 38: 5–37
—— 1979. ‘Pascal: Définitions de nom et géométrie’, in *Méthodes chez Pascal: Actes du colloque tenu à Clermont-Ferrand, 10–13 juin 1976* (Paris: Presses Universitaires de France), ed. by Jean Mesnard, Thérèse Goyet, Philippe Sellier and Dominique Descotes, pp. 77–85

—— 2019. ‘Conclusion’, in *Œuvres d’Ernest Coumet*, vol. 2, ed. by Catherine Goldstein (Besançon: Presses universitaires de Franche-Comté), pp. 295–300 <https://books.openedition.org/pufc/15038> [accessed 5 August 2021]

Crombie, Alistair C. 1981. ‘Mersenne, Marin’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 9, pp. 316–22

—— 1986. ‘Experimental Science and the Rational Artist in Early Modern Europe’, *Daedalus*, 115(3): 49–74

—— 1994. *Styles of Scientific Thinking in the European Tradition: The History of Argument and Explanation Especially in the Mathematical and Biomedical Sciences and Arts*, 3 vols (London: Duckworth)

Dadić, Žarko. 1996. ‘The Early Geometrical Works of Marin Getaldić’, in *Vita Mathematica: Historical Research and Integration with Teaching*, ed. by Ronald Calinger (Washington: Mathematical Association of America), pp. 115–23

Dainville, François de. 1954. ‘L’Enseignement des mathématiques dans les collèges jésuites de France du XVIe au XVIIIe siècle’, *Revue d’histoire des sciences et de leurs applications*, 7(1): 6–21

Danesi, Marcel. 2018. *Ahmes’ Legacy: Puzzles and the Mathematical Mind* (Cham: Springer)

Dasilva, Xosé Manuel, and Helena Tanqueiro (eds). 2011. *Aproximaciones a la autotraducción* (Vigo: Academia del Hispanismo)

Daston, Lorraine J. 1980. ‘Probabilistic Expectation and Rationality in Classical Probability Theory’, *Historia Mathematica*, 7: 234–60

David, Florence N. 1962. *Games, Gods and Gambling: The Origins and History of Probability and Statistical Ideas from the Earliest Times to the Newtonian Era* (London: Griffin)

Davidson, Hugh M. 1965. *Audience, Words, and Art: Studies in Seventeenth-Century French Rhetoric* (Columbus: Ohio State University Press)

Davis, Philip J., and Hersh, Reuben. 1986. *Descartes’ Dream: The World According to Mathematics* (Brighton: Harvester)

—— 1987. ‘Rhetoric and Mathematics’, in *The Rhetoric of the Human Sciences: Language and Argument in Scholarship and Public Affairs,* ed. by John S. Nelson, Allan Megill, and Donald N. McCloskey (Madison: University of Wisconsin Press), pp. 53–68

Dear, Peter. 1988. *Mersenne and the Learning of the Schools* (Ithaca: Cornell University Press)

—— 2009. *Revolutionizing the Sciences: European Knowledge and its Ambitions, 1500–1700*, 2nd edn (Princeton: Princeton University Press)

Declercq, Gilles. 1999. ‘La Rhétorique classique entre évidence et sublime (1650–1675)’, in *Histoire de la rhétorique dans l’Europe moderne (1450–1950)*, 2nd edn, ed. by Marc Fumaroli (Paris: Presses Universitaires de France), pp. 629–706

Delisle, Jean, and Judith Woodsworth (eds). 1995. *Translators through History* (Amsterdam: Benjamins)

Deneire, Tom. 2013. ‘Daniel Heinsius, Martin Opitz and Vernacular Self-Translation’, *Neulateinisches Jahrbuch: Journal of Neo-Latin Language and Literature*, 15: 61–88

—— (ed.). 2014a. *Dynamics of Neo-Latin and the Vernacular: Language and Poetics, Translation and Transfer* (Leiden: Brill)

—— 2014b. ‘Introduction: Dynamics of Neo-Latin and the Vernacular: Introduction and History’, in *Dynamics of Neo-Latin and the Vernacular: Language and Poetics, Translation and Transfer*, ed. by Tom Deneire (Leiden: Brill), pp. 1–17

Desan, Philippe (ed.). 2016. *The Oxford Handbook of Montaigne* (Oxford: Oxford University Press)

Descartes, René. 1657–67. *Lettres de Mr. Descartes*, 3 vols (Paris: Angot)

—— 1659. ‘Lettre à Monsieur (Desargues), lettre XXVII’, in *Lettres de Mr. Descartes*, 3 vols (Paris: Angot), vol. 2, pp. 169–71

—— 1897–1910. *Œuvres de Descartes*, ed. by Charles Adam and Paul Tannery, 12 vols (Paris: Cerf)

—— 1902. ‘Specimina Philosophiæ’, in *Œuvres de Descartes*, ed. by Charles Adam and Paul Tannery, 12 vols (Paris: Cerf), vol. 6, pp. 517–720

—— 1960. ‘Lettre à Mersenne, fin décembre 1637’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 6, pp. 344–47

—— 1998. *Regulæ ad directionem ingenii – Rules for the Direction of the Natural Intelligence: A Bilingual Edition of the Cartesian Treatise on Method*, ed. and trans. by George Heffernan (Amsterdam: Rodopi)

Descotes, Dominique. 1988. ‘Pascal, rhétoricien de la géométrie’, *Cahiers de l’Association internationale des études françaises*, 40: 251–71

—— 1993. *L’Argumentation chez Pascal* (Paris: Presses Universitaires de France)

—— 2001a. *Blaise Pascal: Littérature et géométrie* (Clermont-Ferrand: Presses Universitaires Blaise Pascal)

—— 2001b. ‘Les problèmes de la traduction dans le *Triangle Arithmétique*’, in *La Traduction à la Renaissance et à l’âge classique*, ed. by Marie Vialon (Saint-Etienne: Publications de l’Université de Saint-Etienne), pp. 39–71

—— 2006. ‘Note sur le *Cursus mathematicus* de Pierre Hérigone’, in *Les outils de la connaissance: Enseignement et formation intellectuelle en Europe entre 1453 et 1715*, ed. by Jean-Claude Colbus and Brigitte Hébert (Saint-Étienne: Publications de l’Université de Saint-Étienne), pp. 239–54

—— 2008. ‘Constructions du triangle arithmétique de Pascal’, in *Mathématiciens français du XVIIe siècle: Descartes, Fermat, Pascal*, ed. by Michel Serfati and Dominique Descotes (Clermont-Ferrand: Presses Universitaires Blaise Pascal), pp. 239–80

—— 2020. ‘Sur la genèse du *Traité du triangle arithmétique*’, *Courrier Blaise Pascal*, 41/42: 155–80

De Smet, Ingrid A. R. 2014. ‘Neo-Latin Literature – France: The Seventeenth and Later Centuries: Literature’, in *Brill’s Encyclopaedia of the Neo-Latin*

World, 2 vols, ed. by Philip Ford, Jan Bloemendal and Charles Fantazzi (Leiden: Brill), vol. 2, pp. 1073–76
Devlin, Keith. 2008. *The Unfinished Game: Pascal, Fermat and the Seventeenth-Century Letter that Made the World Modern* (New York: Basic Books)
Diderot, Denis, and Jean le Rond D'Alembert (eds). 1751–65. *Encyclopédie, ou Dictionnaire raisonné des sciences, des arts et des métiers*, 17 vols (Paris: Briasson, David, Le Breton and Durand)
Di Teodoro, Francesco P. 2012. 'Al confine fra autotraduzione e riscrittura: Le redazioni del commento vitruviano di Daniele Barbaro (1567)', in *Autotraduzione: Teoria ed esempi fra Italia e Spagna (e oltre)*, ed. by Marcial Rubio Árquez and Nicola D'Antuono (Milan: Edizioni Universitarie di Lettere Economia Diritto), pp. 217–36
Duché, Véronique (ed.). 2015. *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 1: *XVe et XVIe siècles*
Ducos, Joëlle. 2008. 'Traduire la science en langue vernaculaire: Du texte au mot', in *Science Translated: Latin and Vernacular Translations of Scientific Treatises in Medieval Europe*, ed. by Michèle Goyens, Pieter De Leemans and An Smets (Leuven: Leuven University Press), pp. 181–95
Dugas, René. 1988. *A History of Mechanics*, trans. by John R. Maddox (New York: Dover)
Duhem, Pierre. 2012. *The Origins of Statics: The Sources of Physical Theory*, trans. by Grant F. Leneaux, Victoria N. Vagliente, and Guy H. Wagener (Dordrecht: Springer)
Dunn, Kevin. 1994. *Pretexts of Authority: The Rhetoric of Authorship in the Renaissance Preface* (Stanford: Stanford University Press)
Duportal, Jeanne. 1914. *Étude sur les livres à figures édités en France de 1601 à 1660* (Paris: Champion)
Edwards, A.W.F. 1987. *Pascal's Arithmetical Triangle* (London: Griffin; New York: Oxford University Press)
—— 2003. 'Pascal's Work on Probability', in *The Cambridge Companion to Pascal*, ed. by Nicholas Hammond (Cambridge: Cambridge University Press), pp. 40–52
—— 2013. 'The Arithmetical Triangle', in *Combinatorics: Ancient and Modern*, ed. by Robin Wilson and John J. Watkins (Oxford: Oxford University Press), pp. 167–79
Ehrlich, Shlomit. 2009. 'Are Self-Translators Like Other Translators?', *Perspectives*, 17(4): 243–55
Eisenstein, Elizabeth L. 1979. *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early-Modern Europe*, 2 vols (Cambridge: Cambridge University Press)
—— 2012. *The Printing Revolution in Early Modern Europe* (New York: Cambridge University Press)
Eliot, Simon, and Jonathan Rose (eds). 2007. *A Companion to the History of the Book* (Oxford: Blackwell)

Ernest, Paul. 1982. 'Mathematical Induction: A Recurring Theme', *Mathematical Gazette*, 66(436): 120–25
—— 1998. *Social Constructivism as a Philosophy of Mathematics* (Albany: State University of New York Press)
—— 2013. 'Forms of Knowledge in Mathematics and Mathematics Education: Philosophical and Rhetorical Perspectives', in *Forms of Mathematical Knowledge: Learning and Teaching with Understanding*, ed. by Dina Tirosh (Dordrecht: Kluwer), pp. 67–83
Euclid. 1591. *Euclidis elementorum libri XV*, trans. by Christopher Clavius, 2 vols (Rome: Accolti)
—— 1632. *Les quinze livres des Elements geometriques d'Euclide*, trans. by D. Henrion (Paris: Dedin)
—— 1956. *The Thirteen Books of Euclid's Elements*, trans. and intr. by Sir Thomas L. Heath, 3 vols, 2nd revised edn (New York: Dover)
Fabbri, Natacha. 2007. 'Genesis of Mersenne's *Harmonie universelle*: The Manuscript *Livre de la nature des sons*', *Nuncius*, 22(2): 287–308
Fauvel, John. 1988. 'Cartesian and Euclidean Rhetoric', *For the Learning of Mathematics*, 8(1): 25–29
Febvre, Lucien, and Henri-Jean Martin. 1976. *The Coming of the Book: The Impact of Printing, 1450–1800*, trans. by David Gerard, ed. by Geoffrey Nowell-Smith and David Wootton (London: New Left Books)
Federman, Raymond. 1993. *Critifiction: Postmodern Essays* (Albany: State University of New York Press)
Fellmann, E. A. 1981. 'Fabri, Honoré', in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 4, pp. 505–07
Ferguson, Charles A. 1959. 'Diglossia', *Word*, 15(2): 325–40
Ferreira, Ciro Thadeu Tomazella, and Cibelle Celestino Silva. 2020. 'The Roles of Mathematics in the History of Science: The Mathematization Thesis', *Transversal: International Journal for the Historiography of Science*, 8: 6–25
Filippakopoulou, Maria. 2008. 'Translation Drafts and the Translating Selves', in *Translating Selves: Experience and Identity Between Languages and Literatures*, ed. by Paschalis Nikolaou and Marie-Venetia Kyritsi (London: Continuum), pp. 19–36.
Findlen, Paula (ed.). 2018. *Empires of Knowledge: Scientific Networks in the Early Modern World* (London: Routledge)
Finkelstein, David, and Alistair McCleery. 2005. *An Introduction to Book History* (New York: Routledge)
Fitch, Brian T. 1988. *Beckett and Babel: An Investigation into the Status of the Bilingual Work* (Toronto: University of Toronto Press)
Fletcher, Colin. 1996. 'Mersenne: Sa correspondance et l'*academia parisiensis*', in *L'Europe mathématique: Histoires, mythes, identités / Mathematical Europe: History, Myth, Identity*, ed. by Catherine Goldstein, Jeremy Gray and Jim Ritter (Paris: Maison des Sciences de l'Homme), pp. 143–53
Folena, Gianfranco. 1994. *Volgarizzare e tradurre* (Turin: Einaudi)

Folkerts, Menso. 2005. ‘Remarks on Mathematical Terminology in Medieval Latin: Greek and Arabic Influences’, *Archivum Latinitatis Medii Aevi – Bulletin du Cange,* 63: 149–60
—— 2006. *The Development of Mathematics in Medieval Europe: The Arabs, Euclid, Regiomontanus* (Aldershot: Ashgate)
Ford, Philip, Jan Bloemendal and Charles Fantazzi (eds). 2014. *Brill’s Encyclopaedia of the Neo-Latin World*, 2 vols (Leiden: Brill)
France, Peter (ed.). 1995a. *The New Oxford Companion to Literature in French* (Oxford: Clarendon Press)
France, Peter. 1995. ‘Muse historique, La’, in *The New Oxford Companion to Literature in French*, ed. by Peter France (Oxford: Clarendon Press), p. 550
Franklin, James. 2001. *The Science of Conjecture: Evidence and Probability before Pascal* (Baltimore: The Johns Hopkins University Press)
Fransen, Sietske. 2017a. ‘Introduction: Translators and Translations of Early Modern Science’, in *Translating Early Modern Science*, ed. by Sietske Fransen, Niall Hodson and Karl A. E. Enenkel (Leiden: Brill), pp. 1–16
—— 2017b. ‘Latin in a Time of Change: The Choice of Language as Signifier of a New Science?’, *Isis*, 108(3): 629–35
—— 2020. ‘Jan Baptista van Helmont and his Theory of Translation’, in *Selbstübersetzung als Wissenstransfer*, ed. by Stefan Willer and Andreas Keller (Berlin: Kadmos), pp. 49–70
Fransen, Sietske, Niall Hodson and Karl A. E. Enenkel (eds). 2017. *Translating Early Modern Science* (Leiden: Brill)
Fried, Michael, and Sabetai Unguru. 2001. *Apollonius of Perga’s* Conica: *Text, Context, Subtext* (Leiden: Brill)
Fumaroli, Marc. 1979. ‘Pascal et la tradition rhétorique gallicane’, in *Méthodes chez Pascal: Actes du colloque tenu à Clermont-Ferrand, 10–13 juin 1976* (Paris: Presses Universitaires de France), ed. by Jean Mesnard, Thérèse Goyet, Philippe Sellier and Dominique Descotes, pp. 359–72
—— (ed.). 1999. *Histoire de la rhétorique dans l’Europe moderne (1450–1950)*, 2nd edn, (Paris: Presses Universitaires de France)
—— 2018. *The Republic of Letters*, trans. by Laura Vergnaud (New Haven: Yale University Press)
Gaignières, Aimé de. 1960. ‘Lettre à Mersenne, 17 février 1637’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 6, pp. 190–99
Galderisi, Claudio (ed.). 2011. *Translations médiévales: Cinq siècles de traductions en français au Moyen Âge (XIe–XVe siècles), étude et répertoire*, 3 vols (Turnhout: Brepols)
Gambier, Yves, and Luc van Doorslaer (eds). 2009. *The Metalanguage of Translation* (Amsterdam: Benjamins)
Garber, Daniel. 2004. ‘On the Frontlines of the Scientific Revolution: How Mersenne Learned to Love Galileo’, *Perspectives on Science*, 12(2): 135–63

Garber, Daniel, and Michael Ayers (eds). 2000. *The Cambridge History of Seventeenth-Century Philosophy*, 2 vols (Cambridge: Cambridge University Press)

Genette, Gérard. 1997a. *Palimpsests: Literature in the Second Degree*, trans. by Channa Newman and Claude Doubinsky, foreword by Gerald Prince (Lincoln: University of Nebraska Press)

—— 1997b. *Paratexts: Thresholds of Interpretation*; trans. by Jane E. Lewin, foreword by Richard Macksey (Cambridge: Cambridge University Press)

Gentes, Eva. 2013. 'Potentials and Pitfalls of Publishing Self-Translations as Bilingual Editions', *Orbis Litterarum*, 68(3): 266–81

—— 2020. *Bibliography: Autotraduzione / Autotraducción / Self–Translation*, 39th edn <https://app.box.com/s/57vgm538l7turmaa2vl9gn63190wv6mf > [accessed 23 February 2021]

Giacomotto-Charra, Violaine. 2015. 'Arts et Sciences', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 1: *XVe et XVIe siècles*, ed. by Véronique Duché, pp. 737–828

Gillham, Bill. 2000. *Case Study Research Methods* (London: Continuum)

Gillispie, Charles C. (ed.). 1981. *Dictionary of Scientific Biography*, 16 vols (New York: Scribner).

Gingerich, Owen. 1981. 'Kepler, Johannes' in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 7, pp. 289–312

Giraud, Cédric (ed.). 2019. *A Companion to Twelfth-Century Schools* (Leiden: Brill)

Godeau, Antoine. 1630. 'Preface' in *Des causes de la corruption de l'éloquence*, by Publius Cornelius Tacitus, trans. by Louis Giry (Paris: Chappellain), pp. i–xxv [my pagination]

Goldstein, Carl. 2012. *Print Culture in Early Modern France: Abraham Bosse and the Purposes of Print* (Cambridge: Cambridge University Press)

Goldstein, Catherine (ed.). 2019. *Œuvres d'Ernest Coumet*, vol. 2 (Besançon: Presses universitaires de Franche-Comté) <https://books.openedition.org/pufc/14888> [accessed 5 August 2021]

Goldstein, Catherine, Jeremy Gray and Jim Ritter (eds). 1996. *L'Europe mathématique: Histoires, mythes, identités/Mathematical Europe: History, Myth, Identity* (Paris: Maison des Sciences de l'Homme)

Goodman, David, and Colin A. Russell. 1991. *The Rise of Scientific Europe 1500–1800* (Sevenoaks: Hodder and Stoughton)

Goyens, Michèle, Pieter De Leemans and An Smets (eds). 2008. *Science Translated: Latin and Vernacular Translations of Scientific Treatises in Medieval Europe* (Leuven: Leuven University Press)

Grafton, Anthony. 1981. 'Teacher, Text and Pupil in the Renaissance Classroom: A Case Study from a Parisian College', *History of Universities*, 1: 37–70

—— 2008. ‘Introduction’, in *Scholarly Knowledge: Textbooks in Early Modern Europe*, ed. by Emidio Campi, Simone De Angelis, Anja-Silvia Goeing and Anthony T. Grafton (Geneva: Droz), pp. 11–36

Grattan-Guinness, Ivor. (ed.). 1994. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, 2 vols (London: Routledge)

Grendler, Paul F. 2002. *The Universities of the Italian Renaissance* (Baltimore: The Johns Hopkins University Press)

Grosholtz, Emily, and Herbert Breger (eds). 2000. *The Growth of Mathematical Knowledge* (Dordrecht: Kluwer)

Grosslight, Justin. 2013. ‘Small Skills, Big Networks: Marin Mersenne as Mathematical Intelligencer’, *History of Science*, 51: 337–74

Grutman, Rainier. 1998. ‘Auto-Translation’, in *Routledge Encyclopedia of Translation Studies*, ed. by Mona Baker (London: Routledge), pp. 17–20

—— 2009a. ‘Self-Translation’, in *Routledge Encyclopedia of Translation Studies*, 2nd edn, ed. by Mona Baker and Gabriela Saldanha (London: Routledge), pp. 257–60

—— 2009b. ‘La Autotraducción en la galaxia de las lenguas’, *Quaderns: Revista de traducció*, 16: 123–34

—— 2011. ‘Diglosia y autotraducción vertical (en y fuera de España)’, in *Aproximaciones a la autotraducción*, ed. by Xosé Manuel Dasilva and Helena Tanqueiro (Vigo: Academia del Hispanismo), pp. 69–91

—— 2012. ‘L’auto-traduzione “verticale” ieri et oggi (con esempi dalla Spagna cinquecentesca e novecentesca)’, in *Autotraduzione: Teoria ed esempi fra Italia e Spagna (e oltre)*, ed. by Marcial Rubio Árquez and Nicola D’Antuono (Milan: Edizioni Universitarie di Lettere Economia Diritto), pp. 33–48

—— 2013a. ‘A Sociological Glance at Self-Translation and Self-Translators’, in *Self-Translation: Brokering Originality in Hybrid Culture*, ed. by Anthony Cordingley (London: Bloomsbury), pp. 63–80

—— 2013b. ‘Beckett and Beyond: Putting Self-Translation in Perspective’, *Orbis Litterarum* 68(3): 188–206

—— 2015. ‘L’Autotraduction: De la galerie de portraits à la galaxie des langues’, *Glottopol*, 25: 14–30 < http://glottopol.univ-rouen.fr/numero_25.html#sommaire> [accessed 25 August 2021]

—— 2017. ‘The Self-Translator’s Preface as a Site of Renaissance Self-Fashioning: Bernardino Gómez Miedes’ Spanish Reframing of his Latin “Mirror for Princes”’, in *Untranslatability Goes Global*, ed. by Suzanne Jill Levine and Katie Lateef-Jan (New York: Routledge), pp. 29–45

—— 2019. ‘Self-Translation’, in *Routledge Encyclopedia of Translation Studies*, 3rd edn, ed. by Mona Baker and Gabriela Saldanha (London: Routledge), pp. 514–18

Grutman, Rainier, and Trish Van Bolderen. 2014. ‘Self-Translation’, in *A Companion to Translation Studies*, ed. by Sandra Bermann and Catherine Porter (Chichester: Wiley-Blackwell), pp. 323–32

Guillo, Laurent. 2003. *Pierre I Ballard et Robert III Ballard: Imprimeurs du roy pour la musique, 1599–1673*, 2 vols (Sprimont: Madraga)

Gutbub, Christophe. 2015. ‘Penser la traduction: Que veut dire traduire au XVIe siècle?’, in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 1: *XVe et XVIe siècles*, ed. by Véronique Duché, pp. 183–244

Hacking, Ian. 1975. *The Emergence of Probability: A Philosophical Study of Early Ideas about Probability, Induction and Statistical Inference* (London: Cambridge University Press)

Hahn, Roger. 1971. *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666–1803* (Berkeley: University of California Press)

Hammond, Nicholas (ed.). 2003. *The Cambridge Companion to Pascal* (Cambridge: Cambridge University Press)

Hara, Kokiti. 1962. ‘Pascal et l’induction mathématique’, *Revue d’histoire des sciences et de leurs applications*, 15(3/4): 287–302

—— 1981a. *L’Œuvre mathématique de Pascal*, Memoirs of the Faculty of Letters, XXI (Osaka: Osaka University Press)

—— 1981b. ‘Roberval, Gilles Personne de’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 11, pp. 486–91

Hass, Trine, Noreen Humble and Marianne Pade (eds). 2016. *Renæssanceforum: Journal of Renaissance Studies*, 10: *Latin and the Early Modern World: Linguistic Identity and the Polity from Petrarch to the Habsburg Novelists* <https://www.njrs.dk/rf_10_2016.htm> [accessed 30 March 2021]

Hauchecorne, Bertrand. 2003. *Les Mots et les maths: Dictionnaire historique et étymologique du vocabulaire mathématique* (Paris: Ellipses)

Hawkins, Sir John. 1776. *A General History of the Science and Practice of Music*, 5 vols (London: Payne)

Hayes, Julie Candler. 2009. *Translation, Subjectivity, and Culture in France and England, 1600–1800* (Stanford: Stanford University Press)

Heath, Sir Thomas L. 1956. ‘Introduction’, in *The Thirteen Books of Euclid’s Elements*, trans. and intr. by Sir Thomas L. Heath, 3 vols (Cambridge: Cambridge University Press), vol. 1, pp. 1–151

—— 2014. *Diophantos of Alexandria: A Study in the History of Greek Algebra* (Cambridge: Cambridge University Press)

Heeffer, Albrecht. 2009. ‘On the Nature and Origin of Algebraic Symbolism’, in *New Perspectives on Mathematical Practices: Essays in Philosophy and History of Mathematics*, ed. by Bart Van Kerkhove (Hackensack: World Scientific) pp. 1–27

Heeffer, Albrecht, and Maarten van Dyck (eds). 2010. *Philosophical Aspects of Symbolic Reasoning in Early Modern Mathematics*, Studies in Logic, vol. 26 (London: College Publications)

Henry, John. 2008. *The Scientific Revolution and the Origins of Modern Science*, 3rd edn (Basingstoke: Palgrave Macmillan)

Hérigone, Pierre. 1634–42. *Cursus mathematicus, ou Cours mathématique*, 6 vols (Paris: Piget)
—— 1634a. 'Illustrissimo viro Francisco Bassompetreo', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 1, pp. v–viii [my pagination]
—— 1634b. 'Ad Lectorem', or 'Au Lecteur', in *Cursus mathematicus, ou Cours mathématique*, by Pierre Hérigone, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 1, pp. ix–xii [my pagination]
—— 1634c. 'Prolegomena', or 'Prolegomenes' in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 1, pp. xiii–xx [my pagination]
—— 1634d. 'Euclidis Elementorum Liber Primus: Definitiones', or 'Premier livres des Eléments d'Euclide: Definitions', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 1, pp. xxxii–lx [my pagination]
—— 1634e. 'Euclidis Elementorum', or 'Les Eléments d'Euclide', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 1, pp. 1–800
—— 1634f. 'Arith. Pract', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 2, pp. 1–162
—— 1634g. 'Algebra', or 'L'Algebre', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 2, pp. xv–xvi and 1–296 [my pagination for the paratext]
—— 1634h. 'Mechanica', or 'Les mechaniques', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 3, pp. 283–329
—— 1634i. 'Preface', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 4, pp. iii–viii [my pagination]
—— 1637a. 'Preface', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 5, pp. iii–viii [my pagination]
—— 1637b. *Les six premiers livres des Elements d'Euclide* (Paris: Le Gras)
—— 1637c. 'Etymologie et explication des noms et termes plus obscurs des Mathematiques', in *Les six premiers livres des Elements d'Euclide*, by Pierre Hérigone (Paris: Le Gras), pp. 450–63
—— 1642a. 'Supplementum algebræ', or 'Supplement de l'algebre', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 6, pp. 1–73
—— 1642b. 'Introduction en la chronologie', in *Cursus mathematicus, ou Cours mathématique*, 6 vols, by Pierre Hérigone (Paris: Piget), vol. 6, pp. 159–267
Hesse, Carla. 2002. 'The Rise of Intellectual Property, 700 BC–AD 2000: An Idea in the Balance', *Daedalus*, 131(2): 26–45
Hobbes, Thomas. 1973. *Critique du 'De Mundo' de Thomas White* (Paris: Vrin)
Hofmann, Joseph E. 1981. 'Leibniz: Mathematics', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 8, pp. 160–68

Hokenson, Jan. 2013. 'History and the Self-Translator', in *Self-Translation: Brokering Originality in Hybrid Culture*, ed. by Anthony Cordingley (London: Bloomsbury), pp. 39–60

Hokenson, Jan Walsh, and Marcella Munson. 2007. *The Bilingual Text: History and Theory of Literary Self-Translation* (Manchester: St Jerome)

Hopkins, Brian (ed.). 2009. *Resources for Teaching Discrete Mathematics: Classroom Projects, History Modules, and Articles*, MAA Notes 74 (Washington: Mathematical Association of America)

Horrocks, Geoffrey. 2010. *Greek: A History of the Language and its Speakers*, 2nd edn (Chichester: Wiley-Blackwell)

Houston, Robert A. 2002. *Literacy in Early Modern Europe: Culture and Education 1500–1800*, 2nd edn (Harlow: Longman)

Huber, William A. 2009. 'Book Review: *The Unfinished Game*, by Keith Devlin', *Risk Analysis*, 29(9): 1336–41.

Hughes, Barnabas. 1996. 'Mathematics and Geometry', in *Medieval Latin: An Introduction and Bibliographical Guide*, ed. by Frank A. C. Mantello and Arthur G. Rigg (Washington: The Catholic University of America Press), pp. 348–54

Hunter, Michael. 2001. 'The Correspondence of Robert Boyle', *The British Academy Review*, 5: 28–30

Hyland, Ken. 2003. 'Self-Citation and Self-Reference: Credibility and Promotion in Academic Publication', *Journal of the American Society for Information Science and Technology*, 54(3): 251–59

Itard, Jean. 1981. 'Henrion, Denis or Didier', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 6, pp. 271–72

Jacquot, Jean, and Harold Whitmore Jones. 1973. 'Introduction', in *Critique du 'De Mundo' de Thomas White*, by Thomas Hobbes (Paris: Vrin), pp. 9–102

Jardine, Lisa. 2006. 'A Reputation Restored', in *Robert Hooke: Tercentennial Studies*, ed. by Michael Cooper and Michael Hunter (Aldershot: Ashgate), pp. 247–58

Joby, Christopher. 2014. *The Multilingualism of Constantijn Huygens (1596–1687)* (Amsterdam: Amsterdam University Press)

Juratic, Sabine. 2014. 'La Traduction: Un objet éditorial', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII^e et XVIII^e siècles (1610–1815)*, ed. by Yves Chevrel, Annie Cointre and Yen-Maï Tran-Gervat, pp. 187–248

Kálmán, György C. 1993. 'Some Border Cases of Translation', in *Translation in the Development of Literatures: Proceedings of the XIth Congress of the International Comparative Literature Association, Paris, August 1985*, ed. by José Lambert and André Lefevere (Bern: Peter Lang), pp. 69–72

Karas, Hilla. 2007. 'Le Statut de la traduction dans les éditions bilingues: De l'interprétation au commentaire', in *De la traduction comme commentaire au commentaire de traduction*, ed. by Maryvonne Boisseau (Paris: Presses Sorbonne Nouvelle), pp. 137–59

Katz, Victor J. 2014. *History of Mathematics*, 3rd edn (Harlow: Pearson)

Keen, Elizabeth. 2013. 'Shifting Horizons: The Medieval Compilation of Knowledge as Mirror of a Changing World', in *Encyclopaedism from Antiquity to the Renaissance*, ed. by Jason König and Greg Woolf (Cambridge: Cambridge University Press), pp. 277–300

Khalfa, Jean. 2003. 'Pascal's Theory of Knowledge', in *The Cambridge Companion to Pascal*, ed. by Nicholas Hammond (Cambridge: Cambridge University Press), pp. 122–43

Kitcher, Philip. 1995. 'The Cognitive Functions of Scientific Rhetoric', in *Science, Reason and Rhetoric*, ed. by Henry Krips, J. E. McGuire and Trevor Melia (Pittsburgh: University of Pittsburgh Press; Konstanz: Universitätsverlag Konstanz), pp. 47–66

Kline, Morris. 1972. *Mathematical Thought from Ancient to Modern Times* (New York: Oxford University Press)

Knight, Sarah, and Stefan Tilg (eds). 2015a. *The Oxford Handbook of Neo-Latin* (Oxford: Oxford University Press)

—— 2015b. 'Introduction', in *The Oxford Handbook of Neo-Latin*, ed. by Sarah Knight and Stefan Tilg (Oxford: Oxford University Press), pp. 1–12

Knobloch, Eberhard. 2002. 'The Sounding Algebra: Relations between Combinatorics and Music from Mersenne to Euler', in *Mathematics and Music: A Diderot Mathematical Forum*, ed. by Gerard Assayag, Hans Georg Feichtinger and Jose Francisco Rodrigues (Berlin: Springer), pp. 27–48

—— 2011. 'Kaspar Schott's "Encyclopedia of all Mathematical Sciences"', *Poiesis & Praxis,* 7: 225–47 < https://link.springer.com/article/10.1007/s10202-011-0090-1>

—— 2013. 'Renaissance Combinatorics', in *Combinatorics: Ancient and Modern*, ed. by Robin Wilson and John J. Watkins (Oxford: Oxford University Press), pp. 123–46

Knowlson, James. 1975. *Universal Language Schemes in England and France, 1600–1800* (Toronto: University of Toronto Press)

König, Jason, and Greg Woolf (eds). 2013. *Encyclopaedism from Antiquity to the Renaissance* (Cambridge: Cambridge University Press)

Krause, Corinna. 2006. *Eadar Dà Chànan: Self-Translation, the Bilingual Edition and Modern Scottish Gaelic Poetry* (unpublished PhD dissertation, The University of Edinburgh)

Krips, Henry, J. E. McGuire and Trevor Melia (eds). 1995. *Science, Reason and Rhetoric* (Pittsburgh: University of Pittsburgh Press; Konstanz: Universitätsverlag Konstanz)

Lagarde, Christian, and Helena Tanqueiro (eds). 2013. *L'Autotraduction aux frontières de la langue et de la culture* (Limoges: Lambert-Lucas)

Lagrée, Jacqueline. 1994. 'Mersenne traducteur d'Herbert de Cherbury', *Les Études philosophiques*, 1/2: 25–40

Laliberté, Jadette. 2004. *Formes typographiques: Historique, anatomie, classification* (Quebec: Presses Université Laval)
Lambert, José, and André Lefevere (eds). 1993. *Translation in the Development of Literatures: Proceedings of the XIth Congress of the International Comparative Literature Association, Paris, August 1985* (Bern: Peter Lang)
Langdale, Maria. 1976. 'A Bilingual Work of the Fifteenth Century: Giannozzo Manetti's *Dialogus Consolatorius*', *Italian Studies*, 31(1): 1–16
Leca-Tsiomis, Marie. 2010. 'Michel Le Guern, Nicolas Beauzée, grammairien philosophe, Paris Champion, 2009', *Recherches sur Diderot et sur l'Encyclopédie*, 45: 179–81
Le Dividich, Aude. 2000. 'La Normalisation de l'écriture mathématique aux XVe et XVIIe siècles', in *La Naissance du livre moderne (XIVe–XVIIe siècles): Mise en page et mise en texte du livre français*, ed. by Henri-Jean Martin (Paris: Éditions du Cercle de la Librairie), pp. 340–47
Lenoble, Robert. 1943. *Mersenne ou la naissance du mécanisme* (Paris: Vrin)
—— 1948. 'Quelques aspects d'une révolution scientifique: A propos du troisième centenaire du P. Mersenne (1588–1648)', *Revue d'histoire des sciences et de leurs applications*, 2(1): 53–79
Léon, Antoine, and Pierre Roche. 2008. *Histoire de l'enseignement en France*, 12th edn (Paris: Presses Universitaires de France)
Leonhardt, Jürgen. 2013. *Latin: Story of a World Language*, trans. by Kenneth Kronenberg (Cambridge, MA: Harvard University Press)
Lesure, François. 1965. 'Introduction', in *Harmonie universelle: Contenant la théorie et la pratique de la musique*, by Marin Mersenne, 3 vols (Paris: Centre National de la Recherche Scientifique), vol. 1, pp. v–viii
Levine, Suzanne Jill, and Katie Lateef-Jan (eds). 2017. *Untranslatability Goes Global* (New York: Routledge)
Lieury, Alain. 2013. *Le Livre de la mémoire* (Paris: Dunod)
Lo Bello, Anthony. 2013. *Origins of Mathematical Words: A Comprehensive Dictionary of Latin, Greek, and Arabic Roots* (Baltimore: The Johns Hopkins University Press)
Lodge, R. Anthony. 1993. *French: From Dialect to Standard* (London: Routledge)
Loret, Jean. 1970. 'Extrait de *la Muse historique*', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, p. 903
Lotz-Heumann, Ute (ed.). 2019a. *A Sourcebook of Early Modern European History: Life, Death, and Everything in between* (London: Routledge)
——. 2019b. 'General Introduction', in *A Sourcebook of Early Modern European History: Life, Death, and Everything in between*, ed. by Ute Lotz-Heumann (London: Routledge), pp. 1–19
Macksey, Richard. 1997. 'Foreword', in *Paratexts: Thresholds of Interpretation*, by Gérard Genette, trans. by Jane E. Lewin (Cambridge: Cambridge University Press), pp. xi–xxii

Maiden, Martin, John Charles Smith and Adam Ledgeway (eds). 2010–13. *The Cambridge History of the Romance Languages*, 2 vols (Cambridge: Cambridge University Press)
Maĭstrov, Leonid Efimovich. 1974. *Probability Theory: A Historical Sketch* (New York: Academic Press)
Malet, Antoni, and Daniele Cozzoli. 2010. 'Mersenne and Mixed Mathematics', *Perspectives on Science,* 18(1): 1–8
Mankiewicz, Richard. 2000. *The Story of Mathematics* (London: Cassell)
Mantello, Frank A. C., and Arthur G. Rigg (eds). 1996. *Medieval Latin: An Introduction and Bibliographical Guide* (Washington: The Catholic University of America Press)
Marquant, Hugo. 2016. 'Juan de Ortega OP (¿1480–1568?) y la autotraducción al italiano (1515) de su *Arte de la Aritmética y juntamente de Geometría* (1512)', in *Dominicos 800 años: Labor intelectual, lingüística y cultural*, ed. by Antonio Bueno García, David Pérez Blázquez and Elena Serrano Bertos (Salamanca: San Esteban), pp. 325–41
Martin, Henri-Jean. 1950. 'Guillaume Desprez, libraire de Pascal et de Port-Royal', *Mémoires de la Fédération des Sociétés historiques et archéologiques de Paris et l'Ile-de-France,* 2: 205–28
—— 1969. *Livre, pouvoirs et société à Paris au XVIIe siècle (1598–1701),* 2 vols (Geneva: Droz)
—— 1982. 'Classements et conjonctures', in *Histoire de l'édition française*, ed. by Henri-Jean Martin and Roger Chartier, 4 vols (Paris: Promodis), vol. 1, pp. 429–57
—— 2000 (ed.). *La Naissance du livre moderne (XIVe–XVIIe siècles): Mise en page et mise en texte du livre français* (Paris: Éditions du Cercle de la Librairie)
Martin, Henri-Jean, and Roger Chartier (eds). 1982–85. *Histoire de l'édition française*, 4 vols (Paris: Promodis)
Maseres, Francis (ed.). 1795. *Mr. James Bernoulli's Doctrine of Permutations and Combinations, and Some Other Useful Mathematical Tracts* (London: White and White)
Massa Esteve, Maria Rosa. 2006. 'Algebra and Geometry in Pietro Mengoli (1625–1686)', *Historia Mathematica*, 33: 82–112
—— 2008. 'Symbolic Language in Early Modern Mathematics: The Algebra of Pierre Hérigone (1580–1643)', *Historia Mathematica*, 35: 285–301
—— 2010. 'The Symbolic Treatment of Euclid's *Elements* in Hérigone's *Cursus mathematicus* (1634, 1637, 1642)', in *Philosophical Aspects of Symbolic Reasoning in Early Modern Mathematics*, Studies in Logic, vol. 26, ed. by Albrecht Heeffer and Maarten Van Dyck (London: College Publications), pp. 103–22
—— 2012. 'The Role of Symbolic Language on the Transformation of Mathematics', *Philosophica*, 87: 153–93
McElduff, Siobhán. 2013. *Roman Theories of Translation: Surpassing the Source* (New York: Routledge)

Meli, Domenico Bertoloni. 2004. ‘The Role of Numerical Tables in Galileo and Mersenne’, *Perspectives on Science*, 12(2): 164–90

Mersenne, Marin. 1625. *La Vérité des sciences* (Paris: Toussainct du Bray) <https://gallica.bnf.fr/ark:/12148/bpt6k579276/f4.image > [accessed 23 February 2021]

—— 1627. *Traité de l’harmonie universelle* (Paris: Baudry)

—— 1634. *Les Preludes de l'harmonie universelle, ou Questions curieuses* (Paris: Guenon)

—— 1636a. *Harmonicorum libri* (Paris: Baudry) <https://gallica.bnf.fr/ark:/12148/bpt6k63326258/f2.image> [accessed 23 February 2021]

—— 1636b. *Harmonicorum instrumentorum libri IV* (Paris: Baudry) <https://gallica.bnf.fr/ark:/12148/bpt6k63326258/f202.image> [accessed 23 February 2021]

—— 1647. *Novarum observationum physico-mathematicorum* (Paris: Bertier)

—— 1932–88. *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique)

—— 1955. ‘Lettre à Nicolas-Claude Fabri de Peiresc, 20 mars 1634’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 4, pp. 81–83

—— 1959a. ‘Lettre à Nicolas-Claude Fabri de Peiresc, vers le 20 avril 1635’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 5, pp. 134–40

—— 1959b. ‘Lettre à Nicolas-Claude Fabri de Peiresc, 12 octobre 1635’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 5, pp. 421–23

—— 1959c. ‘Lettre à Nicolas-Claude Fabri de Peiresc, 17 novembre 1635’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 5, pp. 477–82

—— 1965a. *Harmonie universelle: Contenant la théorie et la pratique de la musique*, 3 vols, intro. by François Lesure (Paris: Centre National de la Recherche Scientifique)

—— 1965b. ‘Traitez de la nature des sons, et des mouvemens de toutes sortes de corps’, in *Harmonie universelle: Contenant la théorie et la pratique de la musique*, 3 vols, by Marin Mersenne, intro. by François Lesure (Paris: Centre National de la Recherche Scientifique), vol. 1, pp. i–viii and 1–229 [my pagination for the paratext]

—— 1965c. ‘Traitez de la voix, et des chants’, in *Harmonie universelle: Contenant la théorie et la pratique de la musique*, 3 vols, by Marin Mersenne,

intro. by François Lesure (Paris: Centre National de la Recherche Scientifique), vol. 2, pp. i–viii and 1–180 [my pagination for the paratext]
—— 1965d. ‘Traitez des consonances, des dissonances, des genres, des modes, et de la composition’, in *Harmonie universelle: Contenant la théorie et la pratique de la musique*, 3 vols, by Marin Mersenne, intro. by François Lesure (Paris: Centre National de la Recherche Scientifique), vol. 2, pp. i–xii and 1–442 [my pagination for the paratext]
—— 1965e. ‘Livre de l’utilité de l’harmonie’, in *Harmonie universelle: Contenant la théorie et la pratique de la musique*, 3 vols, by Marin Mersenne, intro. by François Lesure (Paris: Centre National de la Recherche Scientifique), vol. 3, pp. 1–68
—— 1970. ‘Lettre à Theodore Haak, 16 novembre 1640’, in *Correspondance du P. Marin Mersenne, religieux minime*, ed. and annot. by Cornélis de Waard, 17 vols (Paris: Centre National de la Recherche Scientifique), vol. 11, pp. 419–24
—— 2014. *The Correspondence of Marin Mersenne*, in Early Modern Letters Online [EMLO], ed. by Cultures of Knowledge Project, <http://emlo-portal.bodleian.ox.ac.uk/collections/?catalogue=marin-mersenne> [accessed 27 March 2021]
Merzbach, Uta C., and Carl B. Boyer. 2010. *A History of Mathematics*, 3rd edn (Hoboken: Wiley)
Mesnard, Jean. 1964a. ‘Préface’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol.1, pp. 7–19
—— 1964b. ‘Introduction générale’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 1, pp. 25–419
—— 1970a. ‘Celeberrimæ matheseos academiæ Parisiensi’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, pp. 1021–31
—— 1970b. ‘*Traité du triangle arithmétique* et traités connexes’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, pp. 1166–75
—— 1970c. ‘Extrait de *La Muse historique* de Loret (14 avril 1652)’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, pp. 902–03
—— 1991a. ‘De l’esprit géométrique’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 3, pp. 360–89
—— 1991b. ‘Sur le chemin de l’Académie des sciences: Le Cercle du mathématicien Claude Mylon (1654–1660)’, *Revue d’histoire des sciences*, 44(2): 241–51
—— 1992a. ‘Écrits relatifs au concours de la roulette’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 147–88

—— 1992b. ‘Lettres de A. Dettonville’, in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 367–406
Mesnard, Jean, Thérèse Goyet, Philippe Sellier and Dominique Descotes (eds). 1979. *Méthodes chez Pascal: Actes du colloque tenu à Clermont-Ferrand, 10–13 juin 1976* (Paris: Presses Universitaires de France)
Meusnier, Norbert. 1995. ‘La Passe de l’espérance: L’Émergence d’une mathématique du probable au XVIIème siècle’, *Mathématiques et sciences humaines*, 131: 5–28
Michaux, Gérard. 2007. ‘Naissance et développement des académies en France aux XVIIe et XVIIIe siècles’, *Mémoires de l’Académie nationale de Metz*, 73–86
Miglietti, Sara. 2019. ‘“En language latin et francoys communiqué”: Antoine Mizauld’s Astrometeorological Self-Translations’, *Rivista di Storia della Filosofia*, 74(2): 213–31
Mills, Albert J., Gabrielle Durepos and Elden Wiebe (eds). 2010. *Encyclopedia of Case Study Research*, 2 vols (Los Angeles: Sage)
Minnaert, Marcel G. J. 1981. ‘Stevin, Simon’, in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 13, pp. 47–51
Mitchell, Ulysses G. 1911. ‘The Growth of Algebraic Symbolism’, in *Lectures on Fundamental Concepts of Algebra and Geometry*, by John Wesley Young (New York: Macmillan), pp. 226–39
Montgomery, Scott. 2000. *Science in Translation: Movements of Knowledge through Cultures and Time* (Chicago: The University of Chicago Press)
—— 2009. ‘English and Science: Realities and Issues for Translation in the Age of an Expanding *Lingua Franca*’, *The Journal of Specialised Translation*, 11: 6–16
More, St. Thomas. 1963. *The Complete Works of St. Thomas More*, 15 vols (New Haven: Yale University Press)
Moss, Ann. 1994. ‘Being in Two Minds: The Bilingual Factor in Renaissance Writing’, in *Acta Conventus Neo-Latini Hafniensis: Proceedings of the Eighth International Congress of Neo-Latin Studies, Copenhagen, 12 August to 17 August 1991*, ed. by Rhoda Schnur (Binghamton: State University of New York Press), pp. 61–74
Mumma, John, and Marco Panza. 2012. ‘Diagrams in Mathematics: History and Philosophy’, *Synthese*, 186: 1–5
Munday, Jeremy. 2012. *Introducing Translation Studies: Theories and Applications*, 3rd edn (Abingdon: Routledge)
Murdoch, John. 1981. ‘Euclid: Transmission of the *Elements*’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 4, pp. 437–59
Nama, Charles Atangana. 1995. ‘Translators and the Development of National Languages’, in *Translators through History*, ed. by Jean Delisle and Judith Woodsworth (Amsterdam: Benjamins), pp. 25–66

Nannavecchia, Tiziana. 2014. ‘Italian Meta-Reflections on Self-Translation: An Overview of the Debate’, *Tradução em Revista*, 16(1): 95–109

Nate, Richard. 2015. ‘Rhetoric in the Early Royal Society’, in *Rhetoric and the Early Royal Society: A Sourcebook*, ed. by Tina Skouen and Ryan J. Stark (Leiden: Brill), pp. 77–93

Nathan, Henry. 1981. ‘Beaugrand, Jean’, in *Dictionary of Scientific Biography*, ed. by Charles C. Gillispie, 16 vols (New York: Scribner), vol. 1, pp. 541–42

Nelson, Eric. 2012. ‘Translation as Correction: Hobbes in the 1660s and 1670s’, in *Why Concepts Matter: Translating Social and Political Thought*, ed. by Martin J. Burke and Melvin Richter (Leiden: Brill), pp. 119–39

Nelson, John S., Allan Megill and Donald N. McCloskey (eds). 1987a. *The Rhetoric of the Human Sciences: Language and Argument in Scholarship and Public Affairs* (Madison: University of Wisconsin Press)

—— 1987b. ‘Rhetoric of Inquiry’, in *The Rhetoric of the Human Sciences: Language and Argument in Scholarship and Public Affairs*, ed. by John S. Nelson, Allan Megill and Donald N. McCloskey (Madison: University of Wisconsin Press), pp. 3–18

Netz, Reviel. 1999a. ‘Proclus’ Division of the Mathematical Proposition into Parts: How and Why Was it Formulated?’, *The Classical Quarterly*, 49(1): 282–303

—— 1999b. *The Shaping of Deduction in Greek Mathematics: A Study in Cognitive History* (Cambridge: Cambridge University Press)

Nikolaou, Paschalis, and Marie-Venetia Kyritsi (eds). 2008. *Translating Selves: Experience and Identity Between Languages and Literatures* (London: Continuum)

Norton, Glyn P. (ed.) 1999a. *The Cambridge History of Literary Criticism*, vol. 3, *The Renaissance* (Cambridge: Cambridge University Press)

Norton, Glyn P. 1999b. ‘Introduction’, in *The Cambridge History of Literary Criticism*, vol. 3, *The Renaissance*, ed. by Glyn P. Norton (Cambridge: Cambridge University Press), pp. 1–22

Nuchelmans, Gabriel. 2000. ‘Deductive Reasoning’, in *The Cambridge History of Seventeenth-Century Philosophy*, 2 vols, ed. by Daniel Garber and Michael Ayers (Cambridge: Cambridge University Press), vol. 1, pp. 132–46

O’Connor, John J., and Edmund F. Robertson. 1997. ‘Jean-Baptiste Morin’, *MacTutor History of Mathematics Archive* (St Andrew’s: School of Mathematics and Statistics, University of St. Andrews) <https://mathshistory.st-andrews.ac.uk/Biographies/Morin_Jean-Baptiste/> [accessed 24 August 2021]

—— 2006. ‘Pierre Hérigone’, *MacTutor History of Mathematics Archive* (St Andrew’s: School of Mathematics and Statistics, University of St. Andrews) <https://mathshistory.st-andrews.ac.uk/Biographies/Herigone/> [accessed 2 April 2021]

—— 2008. ‘Christopher Clavius’, *MacTutor History of Mathematics Archive* (St Andrew’s: School of Mathematics and Statistics, University of St. Andrews)

<https://mathshistory.st-andrews.ac.uk/Biographies/Clavius/> [accessed 1 September 2021]
—— 2010. ‘Claude Hardy’, *MacTutor History of Mathematics Archive* (St Andrew’s: School of Mathematics and Statistics, University of St. Andrews) <https://mathshistory.st-andrews.ac.uk/Biographies/Hardy_Claude/> [accessed 13 August 2021]
—— 2014. ‘René Descartes’, *MacTutor History of Mathematics Archive* (St Andrew’s: School of Mathematics and Statistics, University of St. Andrews) <https://mathshistory.st-andrews.ac.uk/Biographies/ Descartes/> [accessed 24 August 2021]
Ogilvie, Brian. 2015. ‘Science and Medicine’, in *The Oxford Handbook of Neo-Latin*, ed. by Sarah Knight and Stefan Tilg (Oxford: Oxford University Press), pp. 263–78
Orcibal, Jean, and Lucien Jerphagnon. 2021. ‘Blaise Pascal’, *Encyclopædia Britannica* <https://www.britannica.com/biography/Blaise-Pascal> [accessed 1 April 2021]
Oustinoff, Michaël. 2018. *La Traduction*, 6th edn (Paris: Presses Universitaires de France)
Pal, Carol. 2018. ‘The Early Modern Information Factory: How Samuel Hartlib Turned Correspondence into Knowledge’, in *Empires of Knowledge: Scientific Networks in the Early Modern World*, ed. by Paula Findlen (London: Routledge), pp. 126–58
Pantin, Isabelle. 2000. ‘Latin et langues vernaculaires dans la littérature scientifique européenne au début de l’époque moderne (1550–1635)’, in *Sciences et langues en Europe*, ed. by Roger Chartier and Pietro Corsi (Luxembourg: Office for Official Publications of the European Communities), pp. 41–56
—— 2007. ‘The Role of Translations in European Scientific Exchanges in the Sixteenth and Seventeenth Centuries’, in *Cultural Translation in Early Modern Europe*, ed. by Peter Burke and R. Po-chia Hsia (Cambridge: Cambridge University Press), pp. 163–79
Park, Katherine, and Lorraine Daston (eds). 2006. *The Cambridge History of Science*, 8 vols (Cambridge: Cambridge University Press), vol. 3: *Early Modern Science*
Pascal, Blaise. 1654a. *Numeri figurati, seu ordines numerici* (unpublished)
—— 1654b. *Triangulus arithmeticus* (unpublished)
—— 1665a. *Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere* (Paris: Desprez)
—— 1665b. ‘Traité du triangle arithmétique’, in *Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere*, by Blaise Pascal (Paris: Desprez), pages 1–11
—— 1665c. ‘Divers usages du triangle arithmétique, dont le générateur est l’unité’, ‘Usage du triangle arithmétique pour les ordres numériques’, and ‘Usage du triangle arithmétique pour les combinaisons’, in *Traité du triangle*

arithmetique, avec quelques autres petits traitez sur la mesme matiere, by Blaise Pascal (Paris: Desprez), pages 1–8
—— 1665d. 'Usage du triangle arithmétique, pour determiner les partis qu'on doit faire entre deux joueurs qui jouent en plusieurs parties', and 'Usage du triangle arithmétique pour trouver les puissances des binômes et apotomes', in *Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere*, by Blaise Pascal (Paris: Desprez), pages 1–16
—— 1665e. 'Traité des ordres numériques', 'De numericis ordinibus tractatus', 'De numerorum continuorum productis, seu de numeris qui producuntur ex multiplicatione numerorum serie naturali procedentium', 'Numericarum potestatum generalis resolutio', 'Combinationes', 'Potestatum numericarum summa', and 'De numeris multiplicibus, ex sola characterum numericorum additione agnoscendis', in *Traité du triangle arithmetique, avec quelques autres petits traitez sur la mesme matiere*, by Blaise Pascal (Paris: Desprez), pages 1–48
—— 1779. *Œuvres*, ed. by Charles Bossut, 5 vols (The Hague: Detune)
—— 1858. *Œuvres complètes,* ed. by Charles Lahure, 2 vols (Paris: Hachette)
—— 1908–21. *Œuvres de Blaise Pascal*, ed. by Léon Brunschvicg, Pierre Boutroux and Félix Gazier, 14 vols (Paris: Hachette)
—— 1923-31. *Œuvres complètes,* ed. by Fortunat Strowski, 3 vols (Paris: Ollendorff)
—— 1926-27. *Œuvres*, ed. by Henri Massis, 6 vols (Paris: A la Cité des Livres)
—— 1928-29. *Œuvres*, ed. by Jean Hytier, 6 vols (Paris: Piazza)
—— 1952a. *The Provincial Letters, Pensées, Scientific Treatises* (Chicago: Encyclopædia Britannica)
—— 1952b. 'Treatise on the Arithmetic Triangle', trans. by Richard Scofield, in *The Provincial Letters, Pensées, Scientific Treatises*, by Blaise Pascal (Chicago: Encyclopædia Britannica), pp. 447–73
—— 1954. *Œuvres complètes,* ed. by Jacques Chevalier (Paris: Gallimard)
—— 1959. 'Treatise on the Arithmetic Triangle', trans. by Anna Savitsky, in *A Source Book in Mathematics*, ed. by David E. Smith (New York: Dover), pp. 67–79
—— 1963. *Œuvres complètes*, ed. by Louis Lafuma (Paris: Éditions du Seuil)
—— 1964–92. *Œuvres complètes*, ed. by Jean Mesnard. 4 vols (Bruges: Desclée de Brouwer)
—— 1970a. 'Lettre dédicatoire à monseigneur le Chancelier', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, pp. 331–34
—— 1970b. 'Celeberrimæ matheseos academiæ Parisiensi', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, pp. 1031–35
—— 1970c. 'Lettre de M. Pascal à M. de Fermat, le 29 juillet 1654', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 2, pp. 1137–45

—— 1986. *L'Esprit de la géométrie, De l'art de persuader: Textes et commentaires*, ed. by Bernard Clerté and Martine Lhoste-Navarre (Paris: Bordas)

—— 1991. 'De l'esprit géométrique', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 3, pp. 390–428

—— 1992a. 'Histoire de la roulette, appelée autrement la trochoïde, ou la cycloïde', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 214–24

—— 1992b. 'Historia trochoidis sive cycloidis', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 225–33

—— 1992c. 'Suite de l'histoire de la roulette', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 238–45

—— 1992d. 'Historiae trochoidis sive cycloidis continuatio', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 246–52

—— 1992e. 'Lettre de Monsieur Dettonville à Monsieur de Carcavy', in *Œuvres complètes*, by Blaise Pascal, ed. and annotat. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 4, pp. 413–552

Peletier, Jacques. 1550. *Dialogue de l'ortografe e prononciation françoese* (Poitiers: De Marnes)

Pengelley, David. 2009. 'Pascal's Treatise on the Arithmetical Triangle: Mathematical Induction, Combinations, the Binomial Theorem and Fermat's Theorem', in *Resources for Teaching Discrete Mathematics: Classroom Projects, History Modules, and Articles*, MAA Notes 74, ed. by Brian Hopkins (Washington: Mathematical Association of America), pp. 185–95

Périer, Gilberte. 1964. 'La vie de Monsieur Pascal', in *Œuvres complètes*, by Blaise Pascal, ed. and annot. by Jean Mesnard, 4 vols (Bruges: Desclée de Brouwer), vol. 1, pp. 571–642

Phillips, Henry. 1997. *Church and Culture in Seventeenth-Century France* (Cambridge: Cambridge University Press)

Pickover, Clifford A. 2009. *The Math Book: From Pythagoras to the 57th Dimension, 250 Milestones in the History of Mathematics* (New York: Sterling)

Pinto, Anil J. 2012. 'Reading More Intimately: An Interrogation of Translation Studies Through Self-Translation', *Salesian Journal of Humanities and Social Sciences*, 3(1): 66–72

Platt, John T. 1977. 'A Model for Polyglossia and Multilingualism (with Special Reference to Singapore and Malaysia)', *Language in Society*, 6(3): 361–78

Popovič, Anton. 1976. *Dictionary for the Analysis of Literary Translation* (Edmonton: Department of Comparative Literature, University of Alberta)

Pottinger, David T. 1958. *The French Book Trade in the Ancien Régime, 1500–1791* (Cambridge, MA: Harvard University Press)

Principe, Lawrence M. 2011. *The Scientific Revolution: A Very Short Introduction* (Oxford: Oxford University Press)
Pym, Anthony. 1998. *Method in Translation History* (Manchester: St. Jerome)
Ramminger, Johann. 2016. 'Introduction', in *Renæssanceforum: Journal of Renaissance Studies*, 10: *Latin and the Early Modern World: Linguistic Identity and the Polity from Petrarch to the Habsburg Novelists*, ed. by Trine Hass, Noreen Humble and Marianne Pade, pp. 1–8 <https://www.njrs.dk/10_2016/01_ramminger_introduction.pdf> [accessed 30 March 2021]
Remmert, Volker R., Martina R. Schneider, and Henrik Kragh Sørensen (eds). 2016. *Historiography of Mathematics in the 19th and 20th Centuries* (Cham: Birkhäuser)
Rényi, Alfred. 1970. *Foundations of Probability* (San Francisco: Holden–Day)
—— 1972. *Letters on Probability*, trans. by László Vekerdi (Detroit: Wayne State University Press)
Rey, Alain, and Josette Rey-Debove (eds). 1983. *Le Petit Robert 1: Dictionnaire alphabétique et analogique de la langue française* (Paris: Le Robert)
Reyes, G. Mitchell. 2004. 'The Rhetoric in Mathematics: Newton, Leibniz, the Calculus, and the Rhetorical Force of the Infinitesimal', *Quarterly Journal of Speech*, 90(2): 163–88
Rickard, Peter. 1968. *La Langue française au seizième siècle: Étude suivie de textes* (Cambridge: Cambridge University Press)
—— 1974. *A History of the French Language* (London: Hutchinson)
Rittaud, Benoît, and Albrecht Heeffer. 2014. 'The Pigeonhole Principle, Two Centuries before Dirichlet', *Mathematical Intelligencer*, 36(2): 27–29
Robinson, Douglas. 2002. *Western Translation Theory: From Herodotus to Nietzsche* (Manchester: St Jerome)
Rogers, Ben. 2003. 'Pascal's Life and Times', in *The Cambridge Companion to Pascal*, ed. by Nicholas Hammond (Cambridge: Cambridge University Press), pp. 4–19
Rooney, Anne. 2013. *The Story of Mathematics* (London: Arcturus)
Rose, Mark. 1993. *Authors and Owners: The Invention of Copyright* (Cambridge, MA: Harvard University Press)
Rose, Paul L. 1975. *The Italian Renaissance of Mathematics: Studies on Humanists and Mathematicians from Petrarch to Galileo* (Geneva: Droz)
Rosen, Edward. 1981. 'Commandino, Federico', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 3, pp. 363–65
Rowlett, Russ. 2013. *How Many? A Dictionary of Units of Measurement* (Chapel Hill: Center for Mathematics and Science Education, University of North Carolina)
Rubin, Miri. 2014. *The Middle Ages: A Very Short Introduction* (Oxford: Oxford University Press)
Rubio Árquez, Marcial. 2012. 'Alfonso de Ulloa, autotraductor', in *Autotraduzione: Teoria ed esempi fra Italia e Spagna (e oltre)*, ed. by Marcial

Rubio Árquez and Nicola D'Antuono (Milan: Edizioni Universitarie di Lettere Economia Diritto), pp. 237–54
Rubio Árquez, Marcial, and Nicola D'Antuono (eds). 2012. *Autotraduzione: Teoria ed esempi fra Italia e Spagna (e oltre)* (Milan: Edizioni Universitarie di Lettere Economia Diritto)
Russell, Daniel. 2001. 'Introduction: The Renaissance', in *The Politics of Translation in the Middle Ages and the Renaissance*, ed. by Renate Blumenfeld-Kosinski, Luise von Flotow and Daniel Russell (Ottawa: University of Ottawa Press), pp. 29–35
Saiber, Arielle. 2017. *Measured Words: Computation and Writing in Renaissance Italy* (Toronto: University of Toronto Press)
Salama-Carr, Myriam. 1995. 'Translators and the Dissemination of Knowledge', in *Translators through History*, ed. by Jean Delisle and Judith Woodsworth (Amsterdam: Benjamins), pp. 101–30
Saldanha, Gabriela, and Sharon O'Brien. 2013. *Research Methodologies in Translation Studies* (Manchester: St Jerome)
Sanson, Helena L. 2013. 'The Romance Languages in the Renaissance and after', in *The Cambridge History of the Romance Languages*, ed. by Martin Maiden, John Charles Smith and Adam Ledgeway (Cambridge: Cambridge University Press), vol. 2, pp. 237–82
Santoyo, Julio César. 2005. 'Autotraducciones: Una perspectiva histórica', *Meta* 50(3): 858–67
—— 2006. 'Blank Spaces in the History of Translation', in *Charting the Future of Translation History*, ed. by Georges L. Bastin and Paul F. Bandia (Ottawa: University of Ottawa Press), pp. 11–43
—— 2012. 'L'autotraducción en la Edad Media', in *Autotraduzione: Teoria ed esempi fra Italia e Spagna (e oltre)*, ed. by Marcial Rubio Árquez and Nicola D'Antuono (Milan: Edizioni Universitarie di Lettere Economia Diritto), pp. 63–76
—— 2013a. 'On Mirrors, Dynamics and Self-Translations', in *Self-Translation: Brokering Originality in Hybrid Culture*, ed. by Anthony Cordingley (London: Bloomsbury), pp. 27–38
—— 2013b. 'Esbozo de una historia de la autotraducción', in *L'Autotraduction aux frontières de la langue et de la culture*, ed. by Christian Lagarde and Helena Tanqueiro (Limoges: Lambert-Lucas), pp. 23–35
Sarasohn, Lisa T. 1993. 'Nicolas-Claude Fabri de Peiresc and the Patronage of the New Science in the Seventeenth Century', *Isis*, 84(1): 70–90
Schaaf, William L. 1981a. 'Bachet de Méziriac, Claude-Gaspar', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 1, pp. 367–68
—— 1981b. 'Leurechon, Jean', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 8, pp. 271–72
Schneider, Ivo. 2000. 'The Mathematization of Chance in the Middle of the 17th Century', in *The Growth of Mathematical Knowledge*, ed. by Emily Grosholtz and Herbert Breger (Dordrecht: Kluwer), pp. 59–75

Schnur, Rhoda (ed.). 1994. *Acta Conventus Neo-Latini Hafniensis: Proceedings of the Eighth International Congress of Neo-Latin Studies, Copenhagen, 12 August to 17 August 1991* (Binghamton: State University of New York Press)

Schwartzman, Steven. 1994. *The Words of Mathematics: An Etymological Dictionary of Mathematical Terms Used in English* (Washington: Mathematical Association of America)

Scott, Hamish (ed.). 2015a. *The Oxford Handbook of Early Modern European History, 1350–1750*, 2 vols (Oxford: Oxford University Press)

—— 2015b. 'Introduction: "Early Modern" Europe and the Idea of Early Modernity', in *The Oxford Handbook of Early Modern European History, 1350–1750,* 2 vols (Oxford: Oxford University Press), vol. 1*: Peoples and Places*, ed. by Hamish Scott, pp. 1–33

Sellier, Philippe. 1995. *Pascal et saint Augustin* (Paris: Albin Michel)

Serfati, Michel. 1998. 'Descartes et la constitution de l'écriture symbolique mathématique', *Revue d'histoire des sciences*, 51(2/3): 237–89

—— 2005. *La Révolution symbolique: La Constitution de l'écriture symbolique mathématique* (Paris: Pétra)

Serfati, Michel, and Dominique Descotes (eds). 2008. *Mathématiciens français du XVIIe siècle: Descartes, Fermat, Pascal* (Clermont-Ferrand: Presses Universitaires Blaise Pascal)

Sergescu, Pierre. 1948. 'Mersenne l'animateur (8 septembre 1588 – 1er septembre 1648)', *Revue d'histoire des sciences et de leurs applications*, 2(1): 5–12

Serjeantson, Richard W. 2006. 'Proof and Persuasion', in *The Cambridge History of Science*, 8 vols (Cambridge: Cambridge University Press), vol. 3: *Early Modern Science*, ed. by Katherine Park and Lorraine Daston, pp. 132–75

Shafer, Glenn. 1994. 'The Early Development of Mathematical Probability', in *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, ed. by Ivor Grattan-Guinness (London: Routledge), vol. 2, pp. 1293–1302

Shapiro, Stewart (ed.). 2005a. *The Oxford Handbook of Philosophy of Mathematics and Logic* (Oxford: Oxford University Press)

—— 2005b. 'Logical Consequence, Proof Theory, and Model Theory', in *The Oxford Handbook of Philosophy of Mathematics and Logic* (Oxford: Oxford University Press), ed. by Stewart Shapiro, pp. 651–70

Sharrock, Alison, and Rhiannon Ashley. 2002. *Fifty Key Classical Authors* (London: Routledge)

Shea, William R. 2003. *Designing Experiments and Games of Chance: The Unconventional Science of Blaise Pascal* (Canton, MA: Science History Publications)

Shore, Lys Ann. 1989. 'A Case Study in Medieval Nonliterary Translation: Scientific Texts from Latin to French', in *Medieval Translators and their Craft*, ed. by Jeanette Beer (Kalamazoo: Western Michigan University), pp. 297–327

Shuttleworth, Mark, and Moira Cowie. 1997. *Dictionary of Translation Studies* (Manchester: St. Jerome)

Singh, Simon. 1998. *Fermat's Last Theorem* (London: Fourth Estate)

Skouen, Tina, and Ryan J. Stark (eds). 2015a. *Rhetoric and the Early Royal Society: A Sourcebook* (Leiden: Brill)

Skouen, Tina, and Ryan J. Stark. 2015b. 'Introduction', in *Rhetoric and the Early Royal Society: A Sourcebook*, ed. by Tina Skouen and Ryan J. Stark (Leiden: Brill), pp. 1–50

Slaughter, Mary M. 1982. *Universal Languages and Scientific Taxonomy in the Seventeenth Century* (Cambridge: Cambridge University Press)

Smith, David E. (ed.) 1959. *A Source Book in Mathematics* (New York: Dover)

Snell-Hornby, Mary. 2009. '"What's in a Name?": On Metalinguistic Confusion in Translation Studies', in *The Metalanguage of Translation*, ed. by Yves Gambier and Luc van Doorslaer (Amsterdam: Benjamins), pp. 123–34

Sperti, Valeria. 2017. 'L'Autotraduction littéraire: Enjeux et problématiques', *Revue italienne d'études françaises: Littérature, langue, culture,* 7 [no pagination] <https://doi.org/10.4000/rief.1573>

Stevin, Simon. 1605–08. *Mathematicorum hypomnematum*, 5 vols, trans. by Willebrord Snel (Leiden: Patius)

—— 1605. 'De Statica', in *Mathematicorum hypomnematum*, 5 vols, trans. by Willebrord Snel (Leiden: Patius), vol. 4, pp. 1–155

—— 1634a. *Les Œuvres mathematiques de Simon Stevin*, rev., corr., and trans. by Albert Girard, 2 vols (Leiden: Elsevier)

—— 1634b. 'L'Art pondéraire, ou La Statique', in *Les Œuvres mathématiques de Simon Stevin*, rev., corr., and trans. by Albert Girard (Leiden: Elsevier), vol. 2, pp. 433–520

—— 1955–66. *The Principal Works of Simon Stevin*, 5 vols, ed. by Eduard J. Dijksterhuis, Anton Pannekoek, Robert J. Forbes, Marcel G. J. Minnaert, and Ernst Crone (Amsterdam: Swets and Zeitlinger)

—— 1955. 'Het eerste bouck van de beghinselen der weegconst', in *The Principal Works of Simon Stevin*, 5 vols, ed. by Eduard J. Dijksterhuis, Anton Pannekoek, Robert J. Forbes, Marcel G. J. Minnaert, and Ernst Crone (Amsterdam: Swets and Zeitlinger), vol. 1, pp. 104–223

Stewart, Ian. 2012. *17 Equations that Changed the World* (London: Profile Books)

Stierle, Karlheinz. 1996. 'Translatio Studii and Renaissance: From Vertical to Horizontal Translation', in *The Translatability of Cultures: Figurations of the Space Between*, ed. by Stanford Budick and Wolfgang Iser (Stanford: Stanford University Press), pp. 55–67

Strømholm, Per. 1981. 'Hérigone, Pierre', in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 6, p. 299

Strowski, Fortunat. 1913. *Pascal et son temps*, 3rd edn, 3 vols (Paris: Plon), vol. 3: *Les Provinciales et les Pensées*

Sturdy, David J. 1995. *Science and Social Status: The Members of the Académie des Sciences, 1666–1750* (Woodbridge: The Boydell Press)

Susam-Sarajeva, Şebnem. 2001. ‘Is One Case Always Enough?’, *Perspectives: Studies in Translatology*, 9(3): 167–76

—— 2009. ‘The Case Study Research Method in Translation Studies’, *The Interpreter and Translator Trainer*, 3(1): 37–56

Sylvester, Richard S. 1963. ‘Introduction’, in *The Complete Works of St. Thomas More*, 15 vols (New Haven: Yale University Press), vol. 2, *The History of King Richard III*, ed. by Richard S. Sylvester, pp. i–cvi

Tacitus, Publius Cornelius. 1630. *Des causes de la corruption de l’éloquence*, trans. by Louis Giry (Paris: Chappellain)

Tanqueiro, Helena. 2000. ‘Self-Translation as an Extreme Case of the Author–Translator Dialectic’, in *Investigating Translation: Selected Papers from the 4th International Congress on Translation, Barcelona, 1988*, ed. by Allison Beeby, Doris Ensinger and Marisa Presas (Amsterdam: Benjamins), pp. 55–63

Taton, René (ed.). 1964a. *L’Œuvre scientifique de Pascal* (Paris: Presses Universitaires de France)

—— 1964b. ‘Préface’, in *L’Œuvre scientifique de Pascal*, ed. by René Taton (Paris: Presses Universitaires de France), pp. i–viii.

—— 1981a. ‘Bosse, Abraham’, in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 2, pp. 333–34

—— 1981b. ‘Pascal, Blaise’, in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 10, pp. 330–42

Taylor, Andrew. 2014. ‘Introduction: The Translations of Renaissance Latin’, *Canadian Review of Comparative Literature/Revue Canadienne de Littérature Comparée*, 41(4): 329–53

Tirosh, Dina (ed.). 2013. *Forms of Mathematical Knowledge: Learning and Teaching with Understanding* (Dordrecht: Kluwer)

Tobin, Ruthanne. 2010. ‘Descriptive Case Study’, in *Encyclopedia of Case Study Research*, 2 vols, ed. by Albert J. Mills, Gabrielle Durepos and Elden Wiebe (Los Angeles: Sage), vol. 1, pp. 288–89

Todhunter, Isaac. 1865. *A History of the Mathematical Theory of Probability: From the Time of Pascal to that of Laplace* (Cambridge: Macmillan)

Toniato, Silvia. 2008. ‘Le Lexique mathématique au moyen âge entre latin et langues vernaculaires: Quelques problèmes posés par les traductions’, in *Science Translated: Latin and Vernacular Translations of Scientific Treatises in Medieval Europe*, ed. by Michèle Goyens, Pieter De Leemans and An Smets (Leuven: Leuven University Press), pp. 243–62

Toomer, Gerald J. 1981. ‘Apollonius of Perga’, in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 1, pp. 179–93

—— 1990. ‘Introduction’, in *Apollonius’s Conics Books V to VII: The Arabic Translation of the Lost Greek Original in the Version of the Banū Mūsā*, 2 vols, ed. and trans. by Gerald J. Toomer (New York: Springer), vol. 1, pp. xi–xcv

Topliss, Patricia. 1966. *The Rhetoric of Pascal: A Study of his Art of Persuasion in the 'Provinciales' and the 'Pensées'* (Leicester: Leicester University Press)

Tran-Gervat, Yen-Maï. 2014. 'Penser la traduction', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII^e et XVIII^e siècles (1610–1815)*, ed. by Yves Chevrel, Annie Cointre and Yen-Maï Tran-Gervat, pp. 369–432

Tran-Gervat, Yen-Maï, and Frédéric Weinmann. 2014. 'Discours sur la traduction', in *Histoire des traductions en langue française*, 4 vols (Lagrasse: Verdier), vol. 2: *XVII^e et XVIII^e siècles (1610–1815)*, ed. by Yves Chevrel, Annie Cointre and Yen-Maï Tran-Gervat, pp. 249–367

Turchetti, Mario. 2012. 'Bodin as Self-Translator of his *République*: Why the Omission of "*Politicus*" and Allied Terms from the Latin Version?', in *Why Concepts Matter: Translating Social and Political Thought*, ed. by Martin J. Burke and Melvin Richter (Leiden: Brill), pp. 109–18

University of St. Andrews. 2021. *MacTutor History of Mathematics Archive* (St Andrew's, Scotland: School of Mathematics and Statistics) <https://mathshistory.st-andrews.ac.uk/> [accessed 26 August 2021]

Vanderschelden, Isabelle. 2000. 'Re-Translation', in *Encyclopedia of Literary Translation into English*, 2 vols, ed. by Olive Classe (London: Fitzroy Dearborn), vol. 2, pp. 1154–56

Van der Waerden, Bartel L. 1985. *A History of Algebra: From al-Khwārizmī to Emmy Noether* (Berlin: Springer)

Van Horn Melton, James. 2001. *The Rise of the Public in Enlightenment Europe* (Cambridge: Cambridge University Press)

Van Kerkhove, Bart (ed.). 2009. *New Perspectives on Mathematical Practices: Essays in Philosophy and History of Mathematics* (Hackensack: World Scientific)

Venuti, Lawrence (ed.). 2004. *The Translation Studies Reader*, 2nd edn (New York: Routledge)

Vervliet, Hendrik D. L. 2008. *The Palaeotypography of the French Renaissance: Selected Papers on Sixteenth-Century Typefaces*, 2 vols (Leiden: Brill)

Viala, Alain. 1985. *Naissance de l'écrivain: Sociologie de la littérature à l'âge classique* (Paris: Éditions de Minuit)

Vialon, Marie (ed.). 2001. *La Traduction à la Renaissance et à l'âge classique* (Saint-Etienne: Publications de l'Université de Saint-Etienne)

Vickers, Brian. 1968. *Francis Bacon and Renaissance Prose* (Cambridge: Cambridge University Press)

—— 1988. *In Defence of Rhetoric* (Oxford: Clarendon)

Viguerie, Jean de. 1978. *L'Institution des enfants: L'Éducation en France (XVIe –XVIIIe siècle)* (Paris: Calmann-Lévy)

Vinay, Jean-Paul, and Jean Darbelnet. 2004. 'A Methodology for Translation', trans. by Juan C. Sager and M.-J. Hamel, in *The Translation Studies Reader*, 2nd edn, ed. by Lawrence Venuti (New York: Routledge), pp. 128–37

Vogel, Kurt. 1981. ‘Diophantus Of Alexandria’, in *Dictionary of Scientific Biography*, 16 vols, ed. by Charles C. Gillispie (New York: Scribner), vol. 4, pp. 110–19

Waquet, Françoise. 2001. *Latin or The Empire of a Sign: From the Sixteenth to the Twentieth Centuries*, trans. by John Howe (London: Verso)

Wardhaugh, Benjamin. 2017. *Music, Experiment and Mathematics in England, 1653–1705* (London: Routledge)

Washbourne, Kelly, and Ben Van Wyke (eds). 2018. *The Routledge Handbook of Literary Translation* (Abingdon: Routledge)

Weber, Joseph G. 1976. ‘Pascal and Music: World Harmony in Early Seventeenth-Century France’, *Symposium*, 30(1): 75–91

Wei, Li (ed.). 2007a. *The Bilingualism Reader*, 2nd edn (London: Routledge)

—— 2007b. ‘Introduction to Part One’, in *The Bilingualism Reader*, 2nd edn, ed. by Li Wei (London: Routledge), pp. 27–30

White, Paul. 2015. ‘France’, in *The Oxford Handbook of Neo-Latin*, ed. by Sarah Knight and Stefan Tilg (Oxford: Oxford University Press), pp. 411–26

Willer, Stefan, and Andreas Keller (eds). 2020. *Selbstübersetzung als Wissenstransfer* (Berlin: Kadmos)

Wilson, Robin, and John J. Watkins (eds). 2013. *Combinatorics: Ancient and Modern* (Oxford: Oxford University Press)

Yin, Robert K. 2018. *Case Study Research and Applications: Design and Methods*, 6th edn (Los Angeles: Sage)

Young, John Wesley. 1911. *Lectures on Fundamental Concepts of Algebra and Geometry* (New York: Macmillan)

Zerubavel, Eviatar. 1989. *The Seven Day Circle: The History and Meaning of the Week* (Chicago: The University of Chicago Press)

Zilsel, Edgar. 2013. *The Social Origins of Modern Science*, foreword by Joseph Needham, intr. by Diederick Raven and Wolfgang Krohn, ed. by Diederick Raven, Wolfgang Krohn and Robert S. Cohen (Dordrecht: Springer)

Zuber, Roger. 1968. *Les* “*Belles infidèles*” *et la formation du goût classique: Perrot d’Ablancourt et Guez de Balzac* (Paris: Colin)