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Human Space: The Rise of Euclidism and the Construction of an Early-Modern World, 1400-1800

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Abstract

This essay argues that intellectual historians have overlooked the significance of the return of Euclid's geometric thought to early-modern Europe. Looking at the period between 1400 and 1800, this essay shows how geometric thought not only penetrated into fundamental areas of public discussion but also reorganized knowledge production in ways that allowed Europeans to imagine a world that none of them had ever seen. Euclidian geometry provided the spatial substratum for a broader European project that created the world.

Resumen

Este ensayo sostiene la idea de que los historiadores intelectuales han pasado por alto la importancia del regreso al pensamiento geométrico de Euclides a principios de la era moderna. Si se observa el periodo de tiempo que va desde 1400 hasta 1500 es posible mostrar cómo el pensamiento geométrico no sólo tuvo influencia en áreas de discusión pública que eran fundamentales, sino que también reorganizó la forma de producir conocimiento de una manera tal que permitió a los europeos imaginar un mundo que ninguno había visto anteriormente. La geometría euclidiana proveyó el substrato espacial para un extenso proyecto europeo que creó el mundo.

> [Thomas Hobbes] was forty years old before he looked on geometry; which happened accidentally. Being in a gentleman's library Euclid's Elements lay open, and 'twas the forty-seventh proposition in the first book. He read the proposition. 'By G----+,' said he, 'this is impossible!' So he reads the demonstration of it, which referred him back to such a proof; which referred him back to another, which he also read. And so forth, that at last he was demonstratively convinced of the truth. This made him in love with geometry.
>
> John Aubrey, Brief Lives (1696)[1]

The intellectual history of early-modern Europe is replete with classical "isms". An assortment of scholars has explored the conflicts between an Aristotelianism that emerged dominant from the Middle Ages and insurgent systems, such as Epicureanism (also called Atomism), Platonism, Skepticism, and Stoicism that undermined the Peripatetic consensus.[2] Yet, amidst the contemporary discussion of the early-modern rhetorical battles, the influence on early-modern thought of Euclidism has been overlooked. Rooted in the works of Euclid of Alexandria (fl. 300 BC), Euclidism is a culture of projecting and manipulating space that emerged between 1400 and 1800 thanks to the long-term encounter with classical spatial texts. Not all of these texts were by Euclid, but the most prominent among them were. The republication, beginning in the late fifteenth century, of Euclid's various works made his spatial thought available to the entire European continent, with the result that Euclid crossed nearly every intellectual, religious, linguistic, or disciplinary boundary. For all the clashes between its "isms", the early-modern world shared a common sense of space.

Although Euclid enjoys an honored place among historians of mathematics and historians of architecture, intellectual historians have not considered adequately the effects of his thought on the early-modern world.[3] Classic intellectual-historical works on the late-medieval and Renaissance/Reformation eras barely mention him.[4] The situation is just as

[1] John Aubrey and Richard W. Barber, *Brief Lives: a Modern English Version* (Woodbridge, Suffolk, 1982). 151-152.

[2] Ernst Cassirer, *Die platonische Renaissance in England und die Schule von Cambridge* (Leipzig, 1932), Wilhelm Dilthey, "Auffassung und Analyse des Menschen im 15. und 16. Jahrhundert", in *Wilhelm Diltheys Gesammelte Schriften* (Leipzig, 1921), Hilary Gatti, *Giordano Bruno and Renaissance Science* (Ithaca, NY, 1999), Richard H. Popkin, *The History of Scepticism: from Savonarola to Bayle*, Rev. and expanded ed. (Oxford, 2003), Charles B. Schmitt, *Aristotle and the Renaissance*, Martin Classical Lectures (Cambridge, MA, 1983).

[3] Carl B. Boyer and Uta C. Merzbach, *A History of Mathematics*, 2nd ed. (New York, 1991), Michele Sbacchi, "Euclidism and Theory of Architecture", *Nexus Network Journal* 3 (2001).

[4] William J. Bouwsma, *The Waning of the Renaissance, 1550-1640* (New Haven, CT, 2000), Marcia L. Colish, *Medieval Foundations of the Western Intellectual Tradition, 400-1400*, Yale Intellectual History of the West (New Haven, CT,

bleak for the seventeenth and eighteenth centuries, where much of the literature analyzes early-modern culture as a precursor to the French Revolution.[5] (Works specifically concerned with Thomas Hobbes are exceptions.) A particularly sharp reflection of the general neglect is Isabel Knight's *The Geometric Spirit*, which covers the career of the *philosophe* the Abbé de Condillac without ever mentioning Euclid —an omission made all the more curious by how the title echoes Blaise Pascal's *On the Geometric Spirit* (1657/8), which applied geometric methods of argumentation to theological issues.[6] Knight's oversight reveals a collective blind spot in the intellectual historical literature: historians of thought have not spent nearly enough time thinking about the history of spatial thought.

Intellectual historians have overlooked Euclidism, because its arrival in early-modern Europe caused no fireworks, as did the returns of Stoicism and Epicureanism.[7] Who could argue with points, lines, planes and spheres? This question is obviously rhetorical, but not completely so, because it highlights how we moderns live within the same spatial realm that early moderns constructed. In order to understand more clearly what implicates us in this Euclidian realm, let us consider the proposition that left Hobbes so smitten. It reads, "In right-angled triangles the square on the side subtending the right angle is equal to the squares on the sides containing the right angle."[8] This is the famous Pythagorean theorem, which can be written out as, "the square of the hypotenuse is equal to the sum of the squares of the two other sides", or reduces to the equation $A^2+B^2=C^2$. Unlike Hobbes, most readers will have encountered this theorem before finishing their teens, since geometry, as a basic part of the contemporary curriculum, is a component of the intellectual air we breathe. Moreover, it is important to underscore how mundane this theorem is for us. We would not question why anyone accepted it, only why someone *did not*. Euclid's work was not always accepted with enthusiasm, but that occurred long ago. Some ancient Atomists disagreed vehemently with the

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1997), Anthony Levi, *Renaissance and Reformation: the Intellectual Genesis* (New Haven, CT, 2002), Steven E. Ozment, *The Age of Reform, 1250-1550: an Intellectual and Religious History of Late Medieval and Reformation Europe* (New Haven, CT, 1980).

5 David A. Bell, *Lawyers and Citizens: the Making of a Political Elite in Old Regime France* (New York, 1994), Ernst Cassirer, *The Philosophy of the Enlightenment* (Princeton, NJ, 1968), Peter Gay, *The Enlightenment: An Interpretation*, 2 vols. (New York, 1968), Dena Goodman, *The Republic of Letters: a Cultural History of the French Enlightenment* (Ithaca, NY, 1994), Norman Hampson, *The Enlightenment* (Harmondsworth,, 1968), Paul Hazard, *La crise de la conscience européene (1680-1715)* (Paris, 1935), Paul Hazard, *La pensée européenne au XVIIIeme siècle: de Montesquieu à Lessing* (Paris, 1946), Jonathan I. Israel, *Radical Enlightenment: Philosophy and the Making of Modernity 1650-1750* (Oxford, 2001), Jonathan Irvine Israel, *Enlightenment Contested: Philosophy, Modernity, and the Emancipation of Man, 1670-1752* (Oxford, 2006), Roy Porter, *The Creation of the Modern World: The Untold Story of the British Enlightenment* (New York, 2000).

6 Isabel F. Knight, *The Geometric Spirit: the Abbé de Condillac and the French Enlightenment*, Yale Historical Publications (New Haven, CT, 1968).

7 On Classical Stoicism, see Marcia L. Colish, *The Stoic Tradition from Antiquity to the Early Middle Ages*, 2 vols., Studies in the History of Christian Thought (Leiden, 1985).

8 Euclid, *Euclid's Elements: All Thirteen Books Complete in One Volume*, Thomas L. Heath trans. (Santa Fe, NM, 2002). 35.

Elements, believing that one could not assume continuous space in a universe made up of discontinuous bits of substance. In contrast, early-modern atomists, such as Hobbes, were very much like us, able to read the *Elements* quite happily and to apply the lessons to our world.

Against the backdrop of the fierce clashes between Aristotelians and their critics, intellectual historians have largely missed Euclidism's significance. Francis Bacon, the sworn enemy of Aristotle and contributor to the rise of Atomism in the seventeenth century, encouraged critics of Aristotelianism to, "Hurl calumnies boldly; something always sticks."[9] And the calumnies flew. In contrast, Bacon never took on Euclid. It is, therefore, understandable that historians have concentrated on conflicts rather than commonalities in their explorations of early-modern debates. Moreover, given that the founders of the intellectual historical discipline, such as Hans Baron, Ernst Cassirer, Peter Gay, Arthur O. Lovejoy, and Paul O. Kristeller, confronted, in the 1930s and 40s, a world saturated with de-humanizing "isms", it made sense for them to pursue scrappy, emancipatory systems that had been in conflict with a dominant one.[10] Exploring something that no one opposed —namely spatial thought— and weighing the significance of the event was, thus, not on the agenda.

It is, however, surprising that Euclidism did not become a greater issue for intellectual historians via other paths. The rise of method in the seventeenth century, which owes much to Euclid, has been the subject of study, but has failed to inspire a broader analysis of the *Elements*' role in early-modern thought.[11] More surprising, still, is that the "spatial turn" in intellectual history has yielded nothing of consequence on Euclid.[12] Emerging from the historical-critical work of Michel Foucault, this literature relies heavily on spatial metaphors, such as "web", "field" or "site" in its analysis of texts.[13] The reason is largely doctrinal: Foucault held that all systems were sources of oppression, which meant that commonalities among adherents of competing systems were not worth exploring. And to the extent the Foucault took any notice of spatial structures in early-modern thought, he identified them as

[9] (In the original Latin: "Audacter calumniare; semper aliquid haeret"). Francis Bacon, *The Works of Francis Bacon, Baron of Verulam, Viscount St. Alban, and Lord High Chancellor of England*, 10 vols., vol. 7 (London, 1826). 384, Paolo Rossi, *Francis Bacon: From Magic to Science* (London, 1968). 14-15.

[10] Hans Baron, *The Crisis of the Early Italian Renaissance: Civic Humanism and Republican Liberty in an age of Classicism and Tyranny* (Princeton, NJ, 1955), Ernst Cassirer, *Die Philosophie der Aufklärung* (Tubingen, 1932), Arthur O. Lovejoy, *The Great Chain of Being: a Study of the History of an Idea* (Cambridge, 1964). One may add to this tradition: J. G. A. Pocock, *The Machiavellian Moment: Florentine Political Thought and the Atlantic Republican Tradition* (Princeton, NJ, 1975).

[11] Walter J. Ong, *Ramus: Method, and the Decay of Dialogue, from the Art of Discourse to the Art of Reason* (New York, 1979). D. Burchell, "The Disciplined Citizen: Thomas Hobbes, Neostoicism and the Critique of Classical Citizenship", *Australian Journal of Politics and History* 45 (1999), Joseph S. Freedman, "The Diffusion of the Writings of Petrus Ramus in Central Europe, c. 1570-c. 1630", *Renaissance Quarterly* 46 (1993), Howard Hotson, *Commonplace Learning: Ramism and its German Ramifications, 1543-1630*, Oxford-Warburg studies (Oxford, 2007).

[12] Alan Megill, "The Recepion of Foucault by Historians", *Journal of the History of Ideas* 48 (1987).

[13] Michel Foucault, *The Order of Things: An Archeology of the Human Sciences*, Routledge Classics (London, 1970).

manifestations of larger oppressive forces, which manifested themselves in mental clinics and prisons.[14] Before space could oppress anyone, however, it had to be imagined, and it is the process of imagination that is the subject of this essay.

For the most part, intellectual historians have assumed rather than explored early-modern ways of understanding space.[15] If we are to explore its approach to space, we must begin by noting the massive intellectual changes that were underway. In the early-modern period the spatial realm that Europeans imagined expanded enormously. First, the knowledge of outer space was becoming ever more significant, as the rise of a true astronomical discipline gave Europeans radically new perspectives on the structure and size of the universe. In short, the universe kept getting bigger and humans were no longer at its center. Second, the far-flung nature of the early-modern European globe —with its colonies, its trade networks, and its foreign wars— made putting terrestrial things into their proper place a problem. It was one thing to know that Spanish and Portuguese explorers had stumbled onto a new world; it was quite another to think of that world within a spatial aesthetic.

As an abstract discipline, geometry gave Europeans the conceptual tools with which to imagine both terrestrial and extraterrestrial spaces. All early-modern spatial disciplines, beginning with astronomy and cartography and ending with land surveying, were based on classical geometry. (The latter discipline in particular would be impossible without Euclid's Proposition 47.) Early-modern Europeans learned to imagine space —both seen and unseen— with the tools they acquired from Euclid. For this reason, if we want to understand the early-modern world, we need to consider how it fell in love with geometry.

Early-modern Euclidism began with the print publication of Euclid's greatest surviving work, the *Elements*. Second only to the Bible in the number of editions published, the *Elements* is one of the most influential works ever written.[16] (Other works of Euclid were also published, but editions of the *Elements* were most numerous). The history of this text's return is complicated. The medieval world already hosted multiple Latin translations of the *Elements,* many of which had been made from Arabic sources.[17] The first

[14] Michel Foucault, *Discipline and Punish: the Birth of the Prison* (New York, 1977), Michel Foucault, *Madness and Civilization: a History of Insanity in the Age of Reason*, Richard Howard trans. (New York, 1988), Michel Foucault, *The Birth of the Clinic: an Archaeology of Medical Perception* (New York, 1975).

[15] The classic statement of this approach appears in Foucault, *The Order of Things*. For a critical commentary on Foucault, see Daniel Brewer, "Lights in Space", *Eighteenth-Century Studies* 37 (2004). On Foucault's effect on historical writing, Megill, "The Recepion of Foucault by Historians".

[16] Vincent Jullien, *Philosophie naturelle et géométrie au XVIIe siècle*, Sciences, techniques et civilisations du Moyen Age à l'aube des Lumières, (Paris, 2006). 257. Boyer and Merzbach, *A History of Mathematics*. 119.

[17] H. L. L. Busard, ed., *The First Latin Translation of Euclid's Elements Commonly Ascribed to Adelard of Bath: Books I-VIII and Books X.36-XV.2* (Toronto, 1983), Marshall Clagett, "The Medieval Latin Translations from the Arabic of the Elements of Euclid, with Special Emphasis on the Versions of Adelard of Bath The Medieval Latin Translations from the Arabic of the Elements of Euclid, with Special Emphasis on the Versions of Adelard of Bath", *Isis* 44 (1953), Menso Folkerts, *The Development of Mathematics in Medieval Europe: the Arabs, Euclid, Regiomontanus*, Variorum

early-modern versions inaugurated, however, a new textual lineage that became extremely powerful as a counterpoint to the existing Arabic-Latin tradition. In 1460, for example, Johannes Müller (aka Regiomontanus) did an incomplete Latin version of the *Elements* that was based on Greek manuscripts, many of which had been brought from Byzantium by scholars who were fleeing Ottoman power. Other translations from the Greek followed.

Müller's use of Byzantine manuscripts for his translation highlights a Renaissance trend in the history of geometry. The idea was to use "original" texts to get better translations of ancient thought, since older versions had presumably been distorted. This attitude toward medieval translations is nothing new, as scholars had been translating Greek "originals", since the late fourteenth century. More importantly, it is also Renaissance propaganda, and we need not accept it. As Renaissance culture developed the ability to read and translate Greek, the resulting translations did not start new traditions but invigorated ways of thinking that were already present within European thought. As a result, the textual environment for the *Elements* remained both vigorous and complex for centuries. For example, the first printed version of the *Elements* was a Latin edition of 1482. This translation was, however, not an early-modern product, having been done in the thirteenth-century by Johannes Campanus of Novara.

Two additional print editions appeared within the next fifty years, but these were based on Greek sources. In 1505, Bartolomeo Zamberti published a Latin translation, which competed with that of Campanus for the title of most faithful to the original, with adherents of each side criticizing the other.[18] (One edition of 1516 dealt with the tension between the two schools by publishing both versions together). In 1533, however, an important event occurred, as the *editio princeps* was released.[19] Printed in Basel, this edition was based on Greek sources and, more importantly, was published in Greek, thus making a scholarly version of the "original" text available to a much larger group. With this edition serving as a milestone, other Greek versions soon followed in 1536, 1545, 1549, 1550 and 1557 and 1564.[20]

Collected Studies Series; 811 (Aldershot, 2006), John Murdoch, "Euclid: Transmission of the Elements", in *Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie (New York, NY, 1971).

18 Folkerts, *Mathematics in Medieval Europe*, Ernst Zinner, *Leben und Wirken des Joh. Müller von Königsberg genannt Regiomontanus*, ed. Helmut Rosenfeld and Otto Zeller, Second ed., Milliaria; 10,1 (Osnabrück, 1968). Some examples of versions based on Zamberti: Euclid, *Elementorum geometricorum Lib. 15 ... Phaenomena, Catoptrica et Optica ...*, Bartolomeo Zamberti trans. (Baslieae, 1537). Euclid, *Evclidis Megarensis*. Murdoch, "Euclid: Transmission of the Elements".

19 Euclid and Proclus, *Eukleidou stoichei*on bibl. 15. ek t*on The*onos synousi*on: Eis tou autou to pr*oton, ex*eg*emat*on Proklou bibl. 4. Adiecta præfatiuncula in qua de disciplinis mathematicis nonnihil*, Simon Grynäus and Johann Herwagen trans. (Basileae, 1533).

20 On the editions, see Euclid, *The Thirteen Books of Euclid's Elements*, Thomas Little Heath trans., Second ed., 3 vols., vol. 1 (New York, 1956). 100-103.

The diffusion of competing versions of the *Elements* set the stage for Euclidism's true explosion, as the text then moved from Greek and Latin into Europe's vernaculars. Over the next fifty years, translations appeared in Italian (1543), German (1555), French (1564), English (1570) and Spanish (1576) —although not all of these were based wholly on Greek sources.[21] And with the inception of a vernacular tradition the print environment became even more complicated, as new Latin editions appeared in 1536, 1545, 1557, 1559 and 1566.[22] And this series of editions was punctuated in 1572, with the publication of a definitive Latin edition by the mathematician Federico Commandino. This work was highly respected, because Commandino was both a competent translator and a legitimate mathematician. Moreover, in 1555 and 1562, two more German editions appeared and two French ones joined them in 1564 and 1598.[23]

Remarkably, the Euclid market seems never to have reached saturation, as in the seventeenth century new translations and republications mushroomed. In addition to the Latin versions that seemed to appear almost annually, vernacular versions were published in Dutch (1606, 1617, 1695), English (1651, 1660, 1661, 1685) French (1604, 1615, 1639, 1672), German (1610, 1618, 1634, 1651, 1694, 1697), Italian (1613, 1663, 1680, 1690) and Spanish (1637, 1689).[24] It will be worthwhile to pause over the 1694 German version, which was translated by Anton Ernst Burckhard von Birckenstein. Published out of Vienna, it carried the interesting and revealing title *German Speaking Euclid*, which was a subtle reflection of the linguistic diversity that marked the broader Euclidian literature.[25] On top of all of this, vernacular

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[21] Euclid, *Euclide Megarense philosopho solo introduttore delle scientie mathematice ; diligentemente reassettto, et alla integrita ridotto per il degno professore di tal scientie Nicolo Tartalea, brisciano, secondo le due tradottioni e per commune commodo & vtilita di latino in volgar tradotto ; con una ampla espositione dello istesso tradottore di nouo aggionta ; talmente chiara, che ogni mediocre ingegno, senza la notitia, ouer suffragio di alcun'altra scientia con facilita, sera capace à poterlo intendere.*, Gabriele Tadino, et al. trans. (Stampato in Vinegia, 1543).

[22] Euclid, *Elementa Geometriae Ex Evclide singulari prudentia collecta a Ioanne Vogelin ... Arithmeticae Practicae per Georgium Peurbachium Mathematicum. Cum praefatione Philippi Melanthonis*, ed. Johannes Vögelin (Vitebergae, 1536).

[23] Euclid, *Das sibend, acht vnd neunt buch, des hoch berümbten Mathematici Euclidis Megarensis, in welchen der operationen vnnd regulen aller gemainer rechnung, vrsach grund vnd fundament, angezaigt wirt zu gefallen allen den/ so die Kunst der Rechnung liebhaben/ durch Magistrum Johann Scheybl/ der löblichen universitet zu Tübingen des Euclidis und Arithmetic Ordinarien/ auß dem latein ins teütsch gebracht...* Johann Scheubel trans. (Augspurg, 1555), Euclid, *Die Sechs Erste Bücher Euclidis, Vom anfang oder grund der Geometrj. Jn welchen der rechte grund, nitt allain der Geometrj (versteh alles kunstlichen/ gwisen/ und votailigen gebrauchs des Zirkels/ Linials oder Richtscheittes und andrer werckzeüge/ so zu allerlaj abmessen dienstlich) sonder auch der fürnemsten stuck und vortail der Rechenkunst/ furgeschrieben und dargethan ist./ Auß Griechischer sprach in die Teütsch gebracht, aigentlich erklärt, Auch mit verstentlichen Exempeln, gründlichen Figuren/ und allerlaj den nutz für augen stellenden Anhängen geziert/ Der massenvormals in Teutscher sprach nie gesehen worden... Durch Wilhelm Holtzman, genant Xylander/ von Augspurg*, Guillelmus Xylander trans. (Basel, 1562), Euclid, *Les six premiers livres des Élémens d'Euclide, traduicts et commentez par J. Errard*, J. Errard trans. (Paris, 1598), Euclid, *Les six premiers livres des Eléments d'Euclide* Pierre Forcadel de Béziers trans. (Paris, 1564).

[24] Most of the information in this paragraph comes from the very useful overview of translations in Euclid, *Elements*. 91-113.

[25] Euclid, *Teutsch-Redender Euclides, Oder Acht Bücher Von Denen Anfängen Der Mesz-Kunst : Auff eine neue und gantz leichte Art, Zu Nutzen Allen Generalen, Ingeniern, Natur- und Warheit-Kündigern, Bau-Meistern, Künstlern und Handwerckern / in Teutscher Sprach eingerichtet und bewiesen Durch A. E. B. V. P.*, Anton Ernst Burckhard von Birckenstein trans. (Wienn, 1694).

language barriers also fell within the publishing process itself, as some editions appeared in cities where the local vernacular differed from the text, as in the case of the German version of 1634, which appeared in Amsterdam, the Dutch one of 1638, which was out of Hamburg, and the Spanish edition of 1689, which came from Brussels.[26]

The burgeoning business of translation reflects Euclid's wide appeal in early-modern Europe. His teachings crossed all boundaries, as Aristotelians, Epicureans, and Stoics read him. Catholics and Protestants read him, too, even using each other's editions. And since some well-respected editions continued to be written in Latin, such as those by the Jesuit astronomer Christopher Clavius (1574) or the English mathematician Isaac Barrow (1655), Euclid easily crossed linguistic boundaries —at which point he was often re-translated into a vernacular and published again.[27]

Equally important, as more and more editions appeared, the *Elements* also penetrated schools and universities, where contact with geometry formed generations of students.[28] As the Euclid industry penetrated European curricula, attitudes toward the *Elements* became ever more pedagogical and didactic. The trend was clear already in 1551, the year that the English mathematician Robert Recorde published a workbook —not a full translation— that presented Euclid's theorems to students in a digestible form.[29] The pedagogical overtones were also apparent in Conrad Dasypodius' Latin translation of 1564, which expressly directed itself toward students.[30] Another example of a pedagogical overtone comes from a French translation published in 1683 by the French Jesuit Claude-François Milliet Dechales, which openly celebrated Euclid's simple method of argument:

> The intention of Euclid in this book is to provide the first principles of geometry and to do it in accord with a method. He begins with definitions and the explication of ordinary terms. He then makes several suppositions. And having proposed maxims which natural reason teaches us, he claims that nothing advances without demonstration but to

[26] Euclid, *Die sechs ersten Bücher Euclidis, von den Anfängen und fundamenten der Geometriae; Auß Ioann Petersz Dou niderl. andern Ed. verteutscht* ... Sebastian Curtius trans. (Amsterdam, 1634).

[27] Euclid, *Elementorvm Libri XV. breviter demonstrati, Operâ Is. Barrow, Cantabrigensis*, Isaac Barrow trans. (Cantabrigiae, 1655), Euclid, *Euclidis Elementorum, Libri XIV* (Rome, 1574). On the reputation of Clavius, see S.J. Homann, Frederick A., "Christopher Clavius and the Renaissance of Euclidean Geometry", *Archivum Historicum Societatis Iesu Roma* 52 (1983), Sabine Rommevaux, *Clavius, un clé pour Euclide au XVI siècle* (Paris, 2005). 15-17. On Barrow and Clavius, see Mordechai Feingold, ed., *Before Newton: The Life and Times of Isaac Barrow* (Cambridge, 1990). 351.

[28] François de Dainville and Marie-Madeleine Compère, *L'Éducation des Jésuites: XVIe-XVIIIe siècles* (Paris, 1978). 15-17.

[29] Robert Recorde, *The Pathway to Knowledge, Containing the First Principles of Geometrie, as They May Moste Aptly Be Applied unto Practise, Bothe for Use of Instrumentes Geometricall, and Astronomicall and Also for Proiection of Plattes in Everye Kinde, and therefore Much Necessary for all Sortes of* Men (London, 1551).

[30] Euclid, *Analyseis Geo-||metricæ sex librorum|| Euclidis.|| Primi Et Qvinti Factae À|| Christiano Herlino: Reliqvae Vnà Cvm Com-||mentariis, & Scholiis perbreuibus in eosdem sex libros Geo-||metricos: à Cunrado Dasypodio.|| Cvm Indice ...|| Pro Schola Argentinensi.||*, ed. Christian Herlin (Straßburg, 1566). I had access to a subsequent edition.

> convince a person who wants to accept nothing beyond that which one is required to accept.[31]

More broadly, those educated by the Jesuits, a group that came to include the *philosophes* Voltaire and Denis Diderot, also studied geometry in class.[32] I will return to Jesuit educational strategies below. For now, however, I would like to offer a list of prominent thinkers who published an edition of the *Elements*, or wrote on geometry. It includes, Nicolaus Copernicus, Peter Ramus, Niccolò Tartaglia, Christopher Clavius, Giordano Bruno, Thomas Hobbes, René Descartes, Marin Mersenne, Blaise Pascal, Bernard de Fontenelle, Isaac Newton, and Immanuel Kant.[33] By the end of the eighteenth century, Euclid's influence on European thought was pervasive. There is, thus, no way to understand the intellectual history of early-modern Europe without considering Euclidian space.

Euclidism has a very long pedigree that extends deeply into the Middle Ages. Classical systems of spatial thought permeated medieval culture well before a single humanist had learned Greek.[34] Thus, if we are to put Euclid's effects on early-modern thought into a proper context, we must recognize that the issue is not so much the rediscovery of ancient spatial texts, but the intensification of their effects on an already deeply spatial culture.

Euclid's medieval career is complicated, as well. In the immediate wake of ancient Rome's final dissolution, the Latin-speaking half of Europe had access to Euclid via an incomplete translation done by Boethius around the

[31] Euclid, *Les Elemens D'Euclide, Expliquez D'Une Maniere nouvelle & tres-facile : Avec L'Usage De Chaque Proposition pour toutes les parties des Mathematiques / Par le P. Claude François Millet Dechalles, de la Compagnie de Jesus*, Claude-François Milliet Dechales trans. (Paris, 1683). 1.

[32] Dainville and Compère, *L'Éducation des Jésuites: XVIe-XVIIIe siècles*, Romano Gatto, "Christoph Clavius' "Ordo Servandus in Addiscendis Disciplinis Mathematicis" and the Teaching of Mathematics in Jesuit Colleges at the Beginning of the Modern Era " *Science & Education* 15 (2006).

[33] Nicolaus Copernicus, *De Lateribvs Et Angvlis Triangulorum, tum planorum rectilineorum, tum Sphæricorum, libellus eruditissimus & utilissimus, cum ad plerasque Prolemæi demonstrationes intelligendas, tum uero ad alia multa, scriptus à Clarissimo & doctissimo uiro D. Nicolao Copernico Toronensi. Additus est Canon semissium subtensarum rectarum linearum in Circulo* (Vittembergae, 1542), Euclid, *Euclide megarense acutissimo philosopho, solo introduttore delle scientie mathematice. Diligentemente rassettato, et alla integrita ridotto, per il degno professore di tal scientie Nicolo Tartalea brisciano. Secondo le due tradottioni. Con vna ampla espositione dello istesso tradottore di nuouo aggiunta* Niccolò Tartaglia trans. (Venetia, 1565), Euclid, *Euclides: Elementa mathematica, propositiones et diffinitiones librorum I-XV edidit P. Ramus*, Peter Ramus trans. (Parisiis, 1549). Pascal's works were not published in his lifetime. For a collection of his mathematical works, see Blaise Pascal, *Oeuvres de Blaise Pascal*, vol. 5 (The Hague, 1779). Marin Mersenne, *Euclidis elementorum libri, Apollonii Pergae conica, Sereni de sectione* (Paris, 1626). Newton's "Geometria" was never published either. It is available in Isaac Newton, *The Mathematical Papers of Isaac Newton*, 8 vols., vol. 7 (Cambridge, 1976). 248-400. Bernard le Bovier Fontenelle, *Élémens de la Géometrie de L'Infini* (Paris, 1728).

[34] Clagett, "The Medieval Latin Translations". Marshall Clagett, ed., *Nicole Oresme and the Medieval Geometry of Qualities and Motions: a Treatise on the Uniformity and Difformity of Intensities Known as Tractatus de configurationibus qualitatum et motuum* (Madison, WI, 1968). Although Clagett's main points remain valid, some philological errors have been corrected by Folkerts, *Mathematics in Medieval Europe*. J. A. Bennett, "Geometry in Context in the Sixteenth Century: The View from the Museum", *Early Science and Medicine* 7 (2002).

year 500.[35] Access to Euclid expanded dramatically, however, in the wake of Toledo's fall in 1085, as Latin Christendom slowly acquired a collection of Arabic versions of the *Elements*.[36] Over the next two centuries six Latin translations appeared, the most significant being that of Johannes Campanus of Novara. Completed around 1255, this version dominated Europe until the sixteenth century and became, as I noted above, the first edition of the *Elements* to be published in print form.[37]

The medieval Euclid's effects on the spatial imagination were profound, because he created ways to imagine the space in which the world and the universe existed. In the early twelfth century, for instance, John of Holywood (aka Sacrobosco) wrote *De spera*, a work on spherical geometry that borrowed heavily from Euclid. It introduced all the concepts necessary for thinking about spheres, such as centers, axes, radii, and hemispheres, and attracted multiple commentaries by writers across medieval Europe. It became so popular that it remained in use into the seventeenth century.[38] Sacrobosco's significance lies in the way that it impelled discussions about cosmology. A copy of *De spera* probably made its way to medieval Oxford, where it became the foundation for Robert Grosseteste's late twelfth-century cosmological work *De sphaera*. This text explained the geocentric cosmological system of Ptolemy and Aristotle, which comprised a system of nested spheres at the center of which resided the Earth.[39]

Thanks in part to Sacrobosco, Euclid's influence shaped spatial thought through the thirteenth and fourteenth centuries. The aforementioned Campanus de Novara also wrote a cosmological work entitled *Theory of the Planets*, which applied geometry to the universe and put all the spheres in place.[40] In the fourteenth century the French Schoolman Nicole Oresme also produced a French translation of Sacrobosco's work under the title *Treatise on the Sphere*.[41] Then, following the same path as Grosseteste, he also produced a cosmological work entitled, *The Book of Heaven and Earth*.[42] This text was a translation of and commentary on a Medieval Latin translation of Aristotle's *On the Heaven*, which expounded the geocentric cosmology that

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35 Folkerts, *Mathematics in Medieval Europe*. As an example, see Johannes Sacrobosco, *Sphaerae Tractatus. Ioannis de Sacro Busto Anglici Viri Clariss. Gerardi Cremonensis Theoricae Planetarum Veteres. Georgii Purbachi Theoricae Planetarum Novae...* (Venetiis, 1531).

36 Busard, ed., *Euclid's Elements*.

37 Euclid, *Elementa Geometriae* (Venice, 1482).

38 Lynn Thorndike, *The Sphere of Sacrobosco and Its Commentators* (Chicago, 1949). See, for example, Christoph Clavius, *Christophori Clavii Bambergensis In Sphaeram Ioannis de Sacro Bosco Commentarius* (Romae, 1585).

39 Thomas F. Glick, Steven John Livesey, and Faith Wallis, *Medieval Science, Technology, and Medicine: an Encyclopedia*, Routledge Encyclopedias of the Middle Ages (New York, 2005). 206. Pierre Maurice Marie Duhem, *Medieval Cosmology: Theories of Infinity, Place, Time, Void, and the Plurality of Worlds* (Chicago, 1985).

40 Francis S. Benjamin and G. J. Toomer, eds., *Campanus of Novara and Medieval Planetary Theory: Theorica planetarum* (Madison, WI, 1971), H. L. L. Busard, ed., *Campanus of Novara and Euclid's Elements*, 2 vols., Wissenschaftsgeschichte Boethius (Stuttgart, 2005).

41 Nicole Oresme, "Traité de l'espère", in *Fonds Français* (Paris).

42 Nicole Oresme, *Le Livre du Ciel et du Monde*, Albert Douglas Menut trans. (Madison, WI, 1968).

later influenced Ptolemy. Oresme also wrote a commentary on geometry under the title *Questions on the Geometry of Euclid*, although this text's influence is difficult to gauge, since there are only four known manuscript copies in existence.[43] It is best, thus, to see it as an example of how Euclidian space permeated every corner of medieval discussions about terrestrial and extraterrestrial space.

Against the backdrop of medieval thought, the return of Greek language manuscripts to Latin speaking Europe, beginning in the late fourteenth century, was the crucial factor in Euclid's early-modern rise. The arrival of ostensibly purer manuscripts from Greek-speaking Byzantium, rather than the Arabic-speaking world, gave recent translations of classical works a cachet that medieval versions did not enjoy. The flood of manuscripts piqued the interest of the scholarly world, but the growth in enthusiasm did not so much overcome medieval Euclidism as build upon it. The reason is largely to be found in the text itself. Regardless of when a translation was done, all versions of the *Elements* diffused the same concepts necessary for imagining and manipulating space, including such basic ones as points, lines, planes, and spheres. For example, the first line of the 1482 version of Campanus' translation is "Punctum est cuius pars non est". ("A point is that which has no part").[44] These exact words appear on the first page of Christopher Clavius' Latin translation.[45] Niccolò Tartaglia's republication in 1565 of the original Italian translation of 1543 begins "Il ponto è quello che non ha parte". Wilhelm Holtzman's German translation of 1562 hardly differs at all, having the words, "Ain Punct oder tipfflin/ wirtt das genant/ so khain thail hatt."[46] And Rodrigo Zamorano's Spanish version of 1576 begins, "Punto es, cuya parte es ninguna."[47] Although there were differences among translations, newer ones used the same basic terms and followed the same plan. In this sense, the *Elements* occupied a cultural position very similar to that of the Bible, as its continual republication in similar form produced a common European language of space.

We can gain a sharper view of this spatial culture by considering Books 11-13 of the *Elements*. These begin by discussing parallel planes that are bisected by lines or other planes, before projecting three-dimensional shapes, such as pyramids, cubes, cylinders and spheres.[48] Proposition 17 of Book 12,

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43 Nicole Oresme, *Questiones super geometriam Euclidis*, H. L. L. Busard trans. (Stuttgart, 2010). 2-5, Oresme, "Traité de l'espère", Olaf Pedersen, *Early Physics and Astronomy: a Historical Introduction*, Rev. ed. (Cambridge, 1993). 197-201.

44 Euclid, *Elementa Geometriae* (unpaginated).

45 Euclid, *Evclidis Elementorvm Libri XV : Acceßit XVI. de Solidorvm Regvlarivm cuiuslibet intra quodlibet comparatione ; Omnes perspicuis Demonstrationibvs, accuratisq́ue Scholiis illustrati, ac multarum rerum accessione locupletati*, ed. Christoph Clavius, Nunc tertio ed., summaq́, diligentia recogniti, atque emendati ed. (Colonia, 1591).

46 Euclid, *Euclide megarense acutissimo philosopho*. Fo. IIII.

47 Euclid, *Los seis libros primeros dela Geometria de Evclides. Traduzidos en lengua Española por Rodrigo çamorano Astrologo y Mathematico, y Cathedratico de Cosmographia por su Magestad en la casa de la Contratcion de Seuilla Dirigidos al jllustre señor Luciano Negron, Canonigo dela sancta yglesia de Seuilla*, Rodrigo Zamorano trans. (Seuilla, 1576). Fol. 9.

48 (Quotes from Euclid's *Elements* are taken from a modern edition). Euclid, *Euclid's Elements*. 367-481.

for example, holds: "Given two spheres about the same center, to inscribe in the greater sphere a polyhedral solid which does not touch the lesser sphere at its surface."[49] With this phrase begins a series of proofs through which Euclid establishes that there are only five polyhedral solids and that each of these can be inscribed within a sphere. (These are also known as the Platonic solids. I will have more about Plato and geometry below.) Editions that included all the propositions from book 12 also had a version of Proposition 17.[50] John Keill's *Euclid's Elements of Geometry* (1723), for example, had, "Let two Spheres be supposed about the same Center A. It is required to described a solid Polyhedron in the greater Sphere, not touching the Superficies of the lesser Sphere."[51] Keill's text completes the great importation of Euclid's work that began in the fifteenth century. It was not translated, however, directly from Greek, but from the Latin edition of Commandino. It had all the characteristics I outlined above, including the same opening phrase as other sixteenth-century editions: "A point is that which has no parts or magnitude."[52] Euclid's language of space was universal, regardless of the path it took into print.

All versions of the *Elements* used the same spatial concepts. Those versions that included Books 11-13, however, were crucial to the elaboration of a specifically western way of imagining the world. The ability to imagine spheres, then to cut and splice them with lines and planes was fundamental to early-modern European ways of imagining the globe and the cosmos. Here is another example of spatial projection and manipulation from a contemporary edition of the *Elements*:

> Let the spheres be cut by any plane through the center; Then the sections will be circles, inasmuch as the sphere was produced by the diameter remaining fixed and the semicircle being carried round it; hence, in whatever position we conceive the semicircle to be, the plane carried through it will produce a circle on the circumference of the sphere.[53]

As I noted above, not all editions of Euclid included the complete text. Some left out propositions, while others excluded whole books —stopping at Book 6, or Book 9. Still others included only Books 11-15. (The *Elements* only has thirteen books. Initially, however, two classical commentaries were mistakenly attributed to Euclid). Nonetheless, the sheer number of editions

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49 Ibid. 441.

50 Euclid, *Euclid's Elements of Geometry, From the Latin Translation of Commandine. To Which Is Added, A Treatise of the Nature and Arithmetick of Logarithms; Likewise Another of the Elements of Plain and Spherical Trigonometry; With a Preface, Shewing the Usefulness and Excellency of this Work by Doctor John Keil, F.R.S. and Late Professor of Astronomy in Oxford. Now Done into English* (London, 1723). 268-269.

51 Euclid, *Euclid's Elements of Geometry, From the Latin Translation of Commandine*, John Keill trans. (London, 1723). 268-269.

52 Ibid. 1.

53 Euclid, *Euclid's Elements*. 441.

with accompanying images of abstract space combined with the entry of Euclid into education to guarantee that a swath of Europeans held space in common.[54]

That the text of the *Elements* changed little over time even as it diffused so widely should not occlude the diversity in reactions that Euclid's work provoked in the early-modern world. Indeed, we can learn a good deal about early-modern thought by examining this diversity. Although everyone agreed that Euclid was worth reading, the reasons translators and commentators gave in support varied with the time and place. In general, early-modern writers offered two justifications. First, some held that reading Euclid built character, because it taught people to separate truth from falsehood. Second, others lauded Euclid's benefits to students. The former justification was largely limited to the sixteenth century and used most heavily in Protestant regions. The latter justification appeared at the end of the sixteenth century, and was favored by Catholics.

In the Protestant context, the ethical dimension of Euclid reflects the return of Stoicism in the sixteenth century under the guise of Christian Humanism. Christian humanists were enamored especially of the Roman rhetorician Cicero, whose Stoic concept of duty they applied to religious practice.[55] Works published where Christian Humanism prospered —in Protestant cities, such as Basel, Leipzig, Strasbourg, and Wittenberg— praised Euclid as a teacher of virtue. In 1536, for example, Philipp Melanchthon, who essentially formed German Protestant views of education, wrote in the preface to a Latin edition of the *Elements*:

> Then together with descriptions of geometry they are especially noble. No one without some knowledge sees enough of this art, which would be life demonstrated. No one without it will be a maker of method....There is great praise of geometry, which did not sit fast in inadequate and inferior machines, but flew up to heaven and transported in the heavenly chair human minds from earth cast away, and admiring the working of the world showed us the steering of the one mentioned.[56]

Johann Scheubel, another German Protestant, followed a similar line in his edition of 1550:

[54] Euclid, *Euclid's Elements of Geometry*. 268-269.

[55] Gerhard Oestreich and M. E. H. N. Mout, *Antiker Geist und moderner Staat bei Justus Lipsius (1547-1606): der Neustoizismus als politische Bewegung*, Schriftenreihe der Historischen Kommission bei der Bayerischen Akademie der Wissenschaften (Göttingen, 1989).

[56] Euclid, *Elementa Geometriae*.

> In the meantime neither few nor light as yet are superior to those, who out of the shadow and into the sun are led and whirling about in the common customs of man, whether on private or public business.[57]

Moreover, the same attitudes appeared in the first English language edition of the *Elements*, published in 1570 by Henry Billingsley. In the translator's preface Billingsley begins with the general proposition that knowledge of the arts and sciences:

> teacheth us rules and precepts of vertue, how, in common life amongst men, we ought to walke uprightly: what dueties pertaine to ourselves, what pertaine to the government or good order both of an houshold, and also of a citie or common wealth.[58]

For Billingsley, studying geometry was an essential aspect of a life well lived.

The Stoic backdrop to Billingsley's views is even more vivid in the text's frontispiece (Figure 1). At the bottom, there are personifications of the classic quadrivium: Geometry, Arithmetic, Music, and Astronomy.[59] Above these are images of great classical thinkers: Polybius (203-120 BC), the historian; Strabo (63 BC-AD 24), the geographer; Marinus (70-130), the geographer; Ptolemy (90-168), the astronomer-cosmographer; Aratus (315-240 BC), the didactic, cosmological poet; Hipparchus (190-120 BC) the astronomer. Finally, at the top of the frontispiece is a terrestrial globe, flanked on the right by a geometer holding a compass and on the left a royal personage. The express mixture of the quadrivium with these classical figures draws our attention to profound changes in early-modern thought. All of the figures were Greek-speaking, which underscores the seminal nature of Greek learning to early-modern European culture, and all of them dealt with physical space. Most significantly, however, some of these men, such as Strabo, Marinus, Aratus, and Hipparchus represented disciplines that were undergoing major changes at the time.

It is with the Latin motto, however, that the frontispiece reveals the undercurrent of Stoicism. It reads *virescit vulnere veritas* ("truth grows strong from a wound"), which is probably a gloss on a Stoic motto that was popular in sixteenth-century England *virescit vulnere virtus* ("virtue grows strong from

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57 Euclid, *Evclidis Megarensis, Philosophi & Mathematici Excellentissimi, Sex Libri Priores, De Geometricis principijs, Græci & Latini, unà cum demonstrationibus propositionum, absq[ue] literarum notis, ueris ac proprijs, & alijs quibusdam, usum earum concernentibus, non citra maximum huius artis studiosorum emolumentum adiectis. Algebrae Porro Regvlae, Propter Nvmerorum exempla, passim propositionibus adiecta, his libris præmissæ sunt, eædemq[ue] demonstratæ. Avthore Ioanne Schevbelio, In inclyta Academia Tubingensi Euclidis professore ordinario*, ed. Johann Scheubel (Baslieae, 1550).

58 Euclid, *The Elements of Geometrie of the Most Auncient Philosopher Euclide of Megara: Faithfully (now first) translated into the English toung, by H. Billingsley, Citizen of London. Whereunto are annexed certaine Scholies, Annotations, and Inventiones, of the best Mathematiciens, both of time past, and in this our age*, Henry Billingsley trans. (London, 1570). (unpaginated translator's preface).

59 Colish, *Medieval Foundations of the Western Intellectual Tradition, 400-1400.*

a wound").[60] In order to understand the significance of Stoicism in this context, we must recall that the return of Stoic conception of *pneuma* to early-modern cosmological discussion challenged the regnant Aristotelian-Ptolemaic cosmology. Stoics held that universe was homogenous, because a common substance permeated it, the *pneuma*. This idea corroded the medieval Aristotelian-Ptolemaic universe, which had posited a radical difference between terrestrial and celestial substances.[61] From this perspective, we can understand why early-modern Stoics turned to Euclid. First, with the universe's substances themselves no longer identifying a *locus* on which the Earth and the universe were centered, Euclid provided the conceptual reference points necessary for situating our planet. Second, in the Stoic tradition, the universe is understood as a place for ethical conduct, which meant that Euclid gave to Europeans the underpinnings of a spatial realm that made possible right action.

In Catholic regions, the situation was slightly different. First, Catholic thinkers often cultivated Aristotle's cosmology. The best example is Christopher Clavius, the Jesuit astronomer who taught at the Colegio Romano in Rome and defended Aristotle against competing systems. In this task he failed. But Clavius succeeded in cultivating Euclidian space and produced one of the most important of all the sixteenth-century translation/commentaries of the *Elements*.[62] Appearing in 1574, this edition was hailed as a triumph and was either republished, or cited in other editions as a chief source.[63] Unlike in the Protestant cases above, however, Clavius makes no mention of ethics in his introduction. Instead, he emphasizes the text's utility in mathematical education:

> Namely in this manner, and in our opinion, Euclid without difficulty for students, especially for those, who just as beginners, now begin the first study of mathematics will perceive greater enjoyment and utility.[64]

The emphasis on mathematics is not accidental, as the Jesuits devoted much energy to this discipline's improvement, seeing it as an excellent means for sharpening Jesuit minds for the conflict with Protestantism.[65] One outcome of

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60 Jennifer Summit, "“The Arte of a Ladies Penne”: Elizabeth I and the Poetics of Queenship", *English Literary Renaissance* 26 (1996).

61 Steven J. Dick, *Plurality of Worlds: the Origins of the Extraterrestrial Life Debate from Democritus to Kant* (Cambridge, 1982), Duhem, *Medieval Cosmology: Theories of Infinity, Place, Time, Void, and the Plurality of Worlds*.

62 Peter Dear, *Discipline & Experience: the Mathematical Way in the Scientific Revolution*, Science and its Conceptual Foundations (Chicago, IL, 1995), Homann, "Christopher Clavius and the Renaissance of Euclidean Geometry", Rommevaux, *Clavius*.

63 Euclid, *Evclidis Elementorvm Libri XV : Accessit Liber XVI. De Qvinqve Solidorvm Regularivm inter se comparatione ; Ad Exemplaria R.P. Christophori Clauijè Societ. Iesv, & aliorum collati, emendati & aucti*, ed. Christoph Clavius (Coloniae, 1607).

64 Ibid.

65 On the Jesuits and mathematics, see John L. Heilbron, *Elements of Early Modern Physics* (Berkeley, CA, 1981). 95-96.

this Jesuit imperative was the publication in 1607 of a Chinese translation of Books I-VI of the *Elements* by the Jesuit Matteo Ricci.[66] Clavius's words are also representative, however, of a battle that Clavius waged *within* the Catholic world against the remnants of the trivium —grammar, rhetoric and logic.[67] His goal was to legitimize mathematics against the pretensions of theology, which had emphasized the trivium over the quadrivium in its course of study.

Having covered what separates Protestants and Catholics in their reception of Euclid, I turn now to what united them. Clavius's mention of utility calls attention to what was universal in Euclid's appeal, the notion that understanding how to project space was useful. Consider that the English mathematician Robert Recorde justified the study of geometry in his *The Pathway to Knowledge* (1551) by noting how important geometric skills were to artisans:

> Carpenters, Karvers, Joyners, and Masons, doe willingly acknowledge that they can worke nothing without reason of Geometrie, in so much that they challenge me as a peculiare science for them. But in that they should do wrong to all other men, seyng everie kynde of men have som benefit by me, not only in building, whiche is but other mennes costes, and the arte of Carpenters, Masons, and the other aforesaid, but in their owne private profession, whereof to avoide tediousness I make this rehersall.[68]

And in Brussels the Jesuit Jacob Kresa emphasized geometry's utility by praising the prince who had studied it, while under Kresa's supervision:

> Your Excellency had not reached fifteen years of age, when in geometry he had already studied the *Elements*, in geography he had explored the gulfs, in astronomy had completed starry courses, in military architecture had penetrated fortifications...[69]

The young student to whom Kresa refers began with Euclid and then moved to the mastery of a host of spatial disciplines. Both and Recorde and Kresa's texts refer to Euclid from radically different political and cultural contexts,

[66] Peter M. Engelfriet, *Euclid in China: the Genesis of the First Chinese Translation of Euclid's Elements, Books I-VI (Jihe yuanben, Beijing, 1607) and its Reception up to 1723*, ed. W. L. Idema, Sinica Leidensia (Leiden, 1998).

[67] Dear, *Discipline & Experience*, Homann, "Christopher Clavius and the Renaissance of Euclidean Geometry", Rommevaux, *Clavius*.

[68] Recorde, *The Pathway to Knowledge, Containing the First Principles of Geometrie, as They May Moste Aptly Be Applied unto Practise, Bothe for Use of Instrumentes Geometricall, and Astronomicall and Also for Proiection of Plattes in Everye Kinde, and therefore Much Necessary for all Sortes of Men.* (unpaginated preface).

[69] Euclid, *Elementos Geometricos De Evclides, Los Seis Primeros Libros De Los Planos, Y Los Onzeno, Y Dozeno De Los Solidos: Con Algvnos Selectos Theoremas De Archimedes / Traducidos, y explicados por P. Jacobo Kresa de la Compañia de Jesus, Cathedratico de Mathematicas en los Estudios Reales del Colegio Imperial de Madrid; y en interin en la Armada Real en Cadiz*, Jacobo Kresa trans. (Brvsselas, 1689).

yet they converge on utility as the justification for the study of his works.

We can confirm that utility was a basic undercurrent of Euclid's rise by going back in time. In a sixteenth-century reprint of a Latin translation by Regiomontanus of the astronomical thought of the Arab cosmologist Ahmad Ibn-Muhammad al-Farġānī, we find these words from Regiomontanus:

> Just as the remaining disciplines, geometry goes in use before art, whose use in the house of the Egyptians grew, wherefore the Nile overflowed the limits of the fields every year, they put in place a certain reckoning of measuring, with which they retook the former measures of the fields.[70]

Geometry was inherently justified by the universal need to measure things. Melanchthon, whom I mentioned above, said much the same thing, writing:

> On which account Plato said, to that cause even yet to learn what geometry is, because knowledge of it leads to this, as other arts are easily and directly perceived. But utility in the highest degree of nobility is in measuring the size of the Earth and of the heavens the body and amplitude.[71]

Every early modern who read Euclid was impressed with the tools that his work contained for measuring space.

The early-modern Euclid had multiple faces, each of which was shaped by the intellectual or political agenda of the translator. In the cases noted above, Protestant Stoicism produced one face, while still another emerged from Catholic Aristotelianism.[72] To note this fact is, however, nothing more than wading into the shallow end of the pool. I noted above that early-modern Epicureans such as Thomas Hobbes and Pierre Gassendi embraced him. I will return to the connections between Euclidism and Atomism below, when I discuss Francis Bacon. Here, I will add only that early-modern Platonists and Neoplatonists read Euclid against the backdrop of either the discussions of the Platonic solids in the *Timaeus* of Plato (427-347 BC) or the commentary on the *Elements* by the Neoplatonist Proclus (AD 412-485).[73] More importantly, this Platonic avenue was potentially open to anyone, since the classical past had become common coin. One could appeal to Plato and Aristotle's antiquity as justification for the study of geometry without being a Platonist or

[70] Ahmad Ibn-Muhammad al- Farġānī, *Continentur in hoc libro. Rvdimenta Astronomica Alfragrani. Item Albategnivs Astronomvs Peritis-simvs De Motv Stellarvm, Ex obseruationibus tum proprijs, tum Ptolemæi, ...Item Oratio introductoria in omnes scientias Mathematicas Ioannis de Regiomonte, Patauij habita, cum Alfraganum publice prælegeret. Eivsdem utilissima introductio in elementa Euclidis. Item Epistola Philippi Melanthonis nuncupatoria, ad Senatum Noribergensem. Omnia iam recens prelis publicata* (Norimbergae, 1537). From Regiomontanus' preface (unpaginated).

[71] Euclid, *Elementa Geometriae*. introduction (upaginated).

[72] Charles B. Schmitt, *John Case and Aristotelianism in Renaissance England* (Kingston, 1983).

[73] Ernst Bloch, *Vorlesungen zur Philosophie der Renaissance* (Frankfurt am Main, 1972). John Monfasani, *Byzantine Scholars in Renaissance Italy: Cardinal Bessarion and other Émigrés: Selected Essays* (Aldershot, 1995).

Aristotelian in any meaningful sense. For instance, in the introduction to his translation of the *Elements* the Italian Catholic mathematician Niccolò Tartaglia cited both Aristotle and Plato as authorities on spatial thought, as did the German Protestant Melanchthon, in the preface I cited above.[74]

Having seen how Euclidism crossed intellectual boundaries, we can now consider how his work shifted the soil that extended beneath all of them. Euclidism impelled a dramatic reorganization of knowledge structures that yielded a successor to the classical quadrivium, mixed mathematics. Beginning in the early seventeenth century, a group of spatial disciplines coalesced under this term. By the eighteenth century this collection included astronomy, fortification, geography, gnomonics, horology, hydraulics, optics, surveying, statics, and navigation.[75] All of these disciplines were based on the ability to project geometric space and to take measurements based on spatial projections.

Mixed mathematics began as an anti-Aristotelian term. It first appeared in Francis Bacon's *Of the Proficience and Advancement of Learning* (1605), where it redefined Metaphysics.[76] In the Aristotelian tradition, metaphysics was concerned with things that could not be measured or analyzed discretely. Instead, it pursued what Aristotle considered to be the deeper nature of physical reality. As the philosopher wrote, "We are seeking the principles and causes of things that are, and obviously of things *qua* being."[77] Bacon, in contrast, made metaphysics entirely about discrete things and divided it into two categories that he called "Pure" and "Mixed Mathematics". In the "Pure" category he put Geometry and Arithmetic, since these were theoretical disciplines that underpinned the disciplines in the second category. In mixed mathematics he placed Perspective, Music, Astronomy, Cosmography, Architecture, and Engineering, because these were all based on empirical measurement.

Bacon's redefinition of metaphysics opens a window onto geometry's influence on intellectual structures in early-modern Europe. It was generally agreed that geometry was the origin of mathematics, which in turn made it the foundation for all attempts to measure things. As the Englishman John Newton wrote in 1660, "Geometry is the art of measuring well."[78] In addition, works from other disciplines, such as astronomy and what was once called spherology, often stated expressly that knowledge of geometry was a

74 Engelfriet, *Euclid in China*.
75 Heilbron, *Elements of Early Modern Physics*.
76 Gary I. Brown, "The Evolution of the Term "Mixed Mathematics", *Journal of the History of Ideas* 52 (1991): 81.
77 Aristotle, *The Complete Works of Aristotle: the Revised Oxford Translation*, 2 vols., vol. 2, Bollingen series LXXI (Princeton, NJ, 1984). 1619.
78 John Newton, *Mathematical Elements, in III Parts, the First, Being a Discourse of Practical Geometry, the Three Parts of Continued Quantity, Lines, Planes, and Solides. The Second, a Description and Use of Coelestial and Terrestrial Globes. The Third, the Delineation of the Globe upon the Plain of any Great Circle, according to the Stereographick, or Circular Projection* (London, 1660). 1.

prerequisite for further study in a variety of fields.[79] As an example of the cultural effects that this arrangement had, consider this catchy title from a book published in Berlin in 1793, *Elements of Astronomy along with Mathematical Geometry, Navigation, Chronology, and Gnomonics*.[80] By the late eighteenth century, astronomy had become the Queen of the measuring disciplines, but without geometry, none of astronomy's knowledge would have been possible.

Although Bacon's work is fundamental to the course of mixed mathematics, the trend toward the "spatialization" of European knowledge was apparent earlier. In the introduction to his 1565 translation of the *Elements*, Niccolò Tartaglia noted that for thinkers in the classical and medieval world geometry supported many disciplines, including music, astronomy, astrology, geography, perspective, painting, horology, weights, mechanics and architecture.[81] If we go back further, we can also see Euclidian thought in Peter Ramus, who argued that information should be presented according to the inherent logic of the issue, rather than with reference to Aristotelian categories. He went so far in his work as to insist that information could best be presented on paper in spatial terms, thus connecting the rigor of geometric proofs with the presentation of knowledge on paper.[82] It will, thus, be useful to underscore that in 1549 Ramus issued a Latin translation of the *Elements*.[83]

Mixed mathematics appeared in the wake of Euclid's return and rose in conjunction with the *Elements*' diffusion. By the late sixteenth century, there were dozens of editions of Euclid and many people were using them to call for intellectual reform. The 1570 version of the *Elements* by Henry Billingsley, for example, contained a preface by the philosopher John Dee, in which the latter called for a radical restructuring, based on Mathematics, of what was then called natural philosophy.[84] Dee's call for reform went unheeded. But by the seventeenth century the growing interest in geometry and mathematics at places such as the University of Oxford augured both institutional and intellectual change in England. In 1619, Sir Henry Savile (1549-1622), a noted expert in Greek, endowed two historically significant chairs at the university

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[79] Abel Bürja, *Lehrbuch der Astronomie*, 5 vols., vol. 1 (Berlin, 1794). xxxiii-xxxvii, M. Cornelius Lindner, *Gründliche Anleitung zum nützlichen Gebrauche der Erd- u. Himmels-Kuglen/ Den Anfängern/ in Erlernung Der Geographie und Astronomie, zum Besten: Andern Liebhabern aber dieser Edlen Wissenschaften/ zu weiterer Aufmunterung und Belustigung/ auf eine leichte Art deutlich ausgefertiget, und mit nöthigen Kupfer-Rissen versehen* (Nürnberg, 1726). introduction (unpaginated), John Mair, *A Brief Survey of the Terraqueous Globe* (Edinburgh, 1762). 7-8.

[80] Georg Simon Klügel, *Anfangsgründe der Astronomie nebst der mathematisch Geographie, Schifffahrtskunde, Chronologie und Gnomonik* (Berlin and Stettin, 1793).

[81] Euclid, *Euclide megarense acutissimo philosopho.*

[82] Ong, *Ramus.*

[83] Euclid, *Euclides: Elementa mathematica.*

[84] Stephen Gaukroger, *Francis Bacon and the Transformation of Early-Modern Philosophy* (Cambridge, 2001).

of Oxford: one was the Savilian Chair in Astronomy; the other was in Geometry.[85]

What was going on in Oxford occurred in other parts of Europe, too. Although I began this section with the English Protestant Bacon, it is worthwhile to recall Christopher Clavius did in Rome many of the same things that his northern Protestant cousins were doing, if in the service of Aristotle.[86] It would be difficult to overestimate Clavius' significance for European culture. He is the founder of our modern calendar, which was first instituted in 1582, and published a variety of books on spatial topics, including a commentary on Holywood's *De spere*.[87] In his day, he was considered one of Europe's leading astronomers and his Aristotelianism had a profound impact on the French Catholic Marin Mersenne, who not only published his own Latin edition of the *Elements* but also corresponded with every major scientist of the era, including Thomas Hobbes.[88] Thus, wearing many hats and appearing in many guises, Euclid denies and transgresses all historical boundaries.

Bacon's approach to mixed mathematics had many precursors in geometric thought, but his ideas were not definitive either. As Euclid's influence spread, more people commented on geometry's position in shaping the structures of knowledge. Here is José Ferrer, a Spanish academic, commenting on Clavius and the quadrivium in a cosmological work published in 1677:

> From these four principal sciences, as from four large rivers, are many others born, all of which the priest Christopher Clavius enumerates in the epilogue to the *Elements of Euclid*. Among all of these the most expansive is Astronomy, for the many things into which it expands...[89]

Ferrer highlights the links between geometry and astronomy. Over the centuries, however, the disciplines under Bacon's original rubric changed, increasing in overall number, while dropping some of the originals. In the eighteenth century, for example, the French mathematician Jean-Baptiste le Rond D'Alembert defined the concept of mixed mathematics as bringing to

[85] Robert Goulding, "Henry Savile and the Tychonic World System", *Journal of the Warburg and Courtauld Institutes* 58 (1995), Katherine Neal, "Mathematics and Empire, Navigation and Exploration: Henry Briggs and the Northwest Passage Voyages of 1631", *Isis* 93 (2002), Barbara J. Shapiro, "The Universities and Science in Seventeenth Century England The Universities and Science in Seventeenth Century England", *The Journal of British Studies* 10 (1971).

[86] James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago, 1995).

[87] Clavius, *In Sphaeram*.

[88] Peter Dear, *Mersenne and the Learning of the Schools*, Cornell History of Science Series (Ithaca, NY, 1988).

[89] Leonardo Ferrer, *Astronomica curiosa, y descripcion del mundo superior, y inferior. : contiene la especulacion de los orbes, y globos de entrambas esferas, con admirable artificio: obra hecha de la poderosa mano de dios, provechosa, para qualquier estudioso curioso* (Valencia, 1677). preface (unpaginated).

bear on common experience the ways of mathematical reasoning.[90] The concept was also defined in the *Encyclopédie* (1755), the great work that D'Alembert co-edited with Diderot, as follows:

> Mathematics is divided into...arithmetic, algebra, geometry, astronomy, gnomonics (or the science of sundials), hydrography (or the science of navigation), optics, music, mechanics, astrology, etc.[91]

Mixed mathematics began to dissolve in the middle of the nineteenth century, as each of the disciplines went its own way and non-Euclidian geometries began to emerge. But this dissolution occurred after two centuries of Europe's associating geometry directly with all spatial disciplines.

The early-modern Euclid left a deep impression on Europe's system of knowledge production, making it possible to put knowledge into space. Euclidism's most important effect was to provide the substratum for a spatial realm that I call human space. A cultural product that was imagined by a large group of people who worked in many disciplines, including astronomy and geography, human space had three chief characteristics. First, it was homogeneous, which meant that a person could project his or her perspective back and forth along any geometric figure. Second, it was reflexive, which meant that one could imagine any point as being seen from the perspective of any other point. Finally, it was liminal, working from the outside in, as it implied (and justified) a viewer who related to space by separating himself from it.

Let us consider two examples of human space. The first comes from Book 12 of a reprint of Christopher Clavius' translation that appeared in 1607 in Cologne. (Figure 2.) Here we see the nested spheres that I discussed earlier. This arrangement was crucial to early-modern cosmological discussions, since the nested spheres allowed any human mind to move into outer space and back to Earth in a single moment. In this context, consider the full title of Ferrer's work: *Inquisitive Astronomy and Description of the World Above and Below: Containing Speculations on Orbs and Globes Among both Kinds of Spheres with Admirable Artifice*. Ferrer's entire book moved within the spatial realm defined by Euclid's work. Moreover, since the position of the outer sphere was never truly set, human space was both indeterminate and capacious enough to be integrated with divergent cosmologies. Here is another example from Ferrer:

> Geometry, which concerns the measure, latitude, longitude, depth of the Earth and its center and other things that relate to said globe in matters

[90] Gary I. Brown, "Jean D'Alembert, mixed mathematics and the teaching of mathematics" (Illinois State University, 1987).

[91] Denis Diderot and Jean-Baptiste le Rond D'Alembert, "Catalogue", in *Encyclopédie, ou Dictionnaire Raisonné des Sciences, des Arts et des Métiers*, eds. Denis Diderot and Jean-Baptiste le Rond D'Alembert (Paris, 1755), 2: 760.

> of distance, climate and zones; while also Astronomy, whose mission it is to speculate on the qualities and quantities of the celestial orbs, stars that beautify their diverse movements, operations, arrivals, encounters, correspondences, influxes, which are conducive to their perfect knowledge of these supreme regions.[92]

Aristotelian-Ptolemaic geocentrists could wrap the Earth in Euclidian space as well as Copernican heliocentrists; whereas, those who adhered to a closed universe, such as the Stoics, could use human space as well as Atomists who believed the universe to be infinite.[93] The spatial realm in which humanity located itself slowly came to be understood as a product of the human imagination.

The second, and more concrete, example comes from Thomas Dilworth's *A New and Complete Description of the Terrestrial and Celestial Globes, with their Several Uses* (1775). At the beginning of the work, the author considers the perspective of the viewer with respect to globes:

> That the Spectator, when he observes the starry Orb, conceives himself in the midst of a vast Concave, or hollow expanse; and when he observes the Stars on the celestial *Globe*, imagines himself on the out-side of them.[94]

This quote takes us deep into the structure of the spatial aesthetic that Euclidism cultivated. Human space is coherent, because a viewer imposes the relationship of the various points that exists within the system.

With the parallels between Clavius and Harris in mind, I will now examine what I consider to be the most prominent examples of human space: paired celestial and terrestrial globes. Nothing made Euclid more tactile than celestial and terrestrial globes. Yet, with perhaps the exception of the *Elements*, it is difficult to find any early-modern phenomenon that intellectual historians have overlooked more fully. First produced around the turn of the fifteenth century by mathematicians, most of whom had read Euclid, globes spread far and wide and, by the eighteenth century, a large number of people had access to them. More significantly, globes worked regardless of the cosmology of the viewer. Consider the work of the French cosmographer Allain Manesson-Mallet. In his *Description of the Universe* (1685) he simply noted that all globes are "artificial".[95] And when he

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92 Ferrer, *Astronomica curiosa*. unpaginated preface.

93 Dick, *Plurality of Worlds*, Max Jammer, *Concepts of Space: The History of Theories of Space in Physics*, Second ed. (Cambridge, MA, 1969), Alexandre Koyré, *From the Closed World to the Infinite Universe* (New York, 1957).

94 Thomas Dilworth, *A New and Complete Description of the Terrestrial and Celestial Globes, with their Several Uses* (London, 1775). 1.

95 Allain Manesson-Mallet, *Description De L'Univers : Contenant Les Differents Systemes Du Monde, Les Cartes generales & particulieres de la Geographie Ancienne & Moderne: Les Plans & les Profils des principales Villes & des autres lieux plus*

discussed the arguments for and against heliocentric and geocentric systems he took no position on the merits of either, even though geocentrism was in full retreat, by that time.[96] Irrespective of systemic commitment, every viewer of globes used human space to understand his place.

Now we will consider the history of globes more narrowly. Like Euclidism, globes are a product of Renaissance spatial culture. The first globe produced in Europe since classical times dates to 1493, when Martin Behaim completed a terrestrial globe for the town notables of Nuremberg. Behaim spent most of his career in Portugal, acquiring geographic knowledge from mariners who were striking out into the world. Significantly, this globe had a meridian and latitudinal and longitudinal lines, which he probably borrowed from Ptolemy's *Geographia*, which had only been republished in 1477.[97] This globe was merely a first step, however, as paired globes rapidly took over.[98] In 1517, the mathematician Johannes Schöner (1477-1547), residing in Nuremberg, produced the first pair of celestial and terrestrial globes.[99] Schöner lived a varied life, being, among other things, an ordained Catholic Priest, mathematician, astronomer, and Protestant convert. Hence, in addition to crossing the same borders Euclid did, Schöner's background gave him the skills to apply geometry to methods of imagining the physical world.[100]

The best example of Schöner's efforts at organizing space is the *Little Work of Geography* (1533), a short text that explained the basics of geography through a discussion of how to build globes.[101] Figure 3 comes from this book and represents perfectly the role of human space in the emergence of global thought, as it has a terrestrial globe placed inside a sketch of an armillary

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considerables de la Terre; avec les Portraits des Souverains qui y commandent, leurs Blasons, Titres & Livrées: Et les Moeurs, Religions, Gouvernemens & divers habillemens de chaque Nation ... 5 vols., vol. 1 (Paris, 1685). 2.

96 Ibid. 64-70.

97 Tony Campbell, *The Earliest Printed Maps, 1472-1500* (Berkeley, CA, 1987). The first edition was printed in Bologna. Two more editions followed, one published in Rome in 1478 and another in Ulm in 1486. Margriet Hoogvliet, "The Medieval Texts of the 1486 Ptolemy Edition by Johann Reger of Ulm", *Imago Mundi* 54 (2002).

98 G. R. Crone, *Maps and their Makers: an Introduction to the History of Cartography* (London, 1953). 64-67. There may have been an earlier globe: Jósef Babciz, "The Celestial and Terrestrial Globes of the Vatican Library, Dating from 1477, and their Maker Donnus Nicolaus Germanus (ca 1420- ca 1490)", *Der Globusfreund: Wissenschaftliche Zeitschrift für Globenkunde* 35/37 (1987).

99 Elly Dekker and P. C. J. van der Krogt, *Globes from the Western World* (London, 1993), Jacob Hess, "On Some Celestial Maps and Globes of the Sixteenth Century", *Journal of the Warburg and Courtauld Institutes* 30 (1967), Thomas Horst, "Der Niederschlag von Entdeckungsreisen auf Globen des frühen 16. Jahrdunderts", *Der Globusfreund: Wissenschaftliche Zeitschrift für Globenkunde* 55/56 (2009).

100 Johann Gabriel Doppelmayr, *Historische Nachricht Von den Nürnbergischen Mathematicis und Künstlern, welche fast von dreyen Seculis her Durch ihre Schrifften und Kunst-Bemühungen die Mathematic und mehreste Künste in Nürnberg vor andern trefflich befördert/ und sich um solche sehr wohl verdient gemacht/ zu einem guten Exempel, und zur weitern rühmlichen Nachahmung / In Zweyen Theilen an das Liecht gestellet, Auch mit vielen nützlichen Anmerckungen und verschiedenen Kupffern versehen von Johann Gabriel Doppelmayr, Der Kayserl. Leopoldino-Carolinischen Academiæ Naturæ Curiosorum, auch der Königl. Preußischen Societät der Wissenschaften Mitgliedt und Professore Publ. Mathematum* (Nürnberg, 1730). 45-50, Sven Hauschke, "Kurfürst Johann Friedrich von Sachsen und der Astronom und Mathematiker Johannes Schöner: Das Globenpaar von 1533/1534 in Weimar", *Der Globusfreund: Wissenschaftliche Zeitschrift für Globenkunde* 51/52 (2005).

101 Johannes Schöner, *Opusculum geographicum ex diversorum libris ac cartis summa cura & diligentia collectum, accomodatum ad recenter elaboratum ab eodem globum descriptionis terrenae* (Nürnberg, 1533).

sphere. This image gives us a sense for, on the one hand, the spatial realm in which early-moderns situated the Earth, as the viewer is necessarily placed above the realm in which the Earth is wrapped, and, on the other, the medieval backdrop of this spatial aesthetic, since the armillary sphere was a medieval invention. The two most significant influences on Schöner's approach to projecting space are the astronomer Regiomontanus, whom I mentioned above, and the growing literature on geometry. Indeed, with reference to the latter, the title of the book's twelfth chapter is: "On the distance of place in the terrestrial globe found on the path of geometry", in which Schöner explained how to measure distances between terrestrial points, before turning, in the book's next section, to an actual description of the earth.[102]

From this perspective it was relatively easy for Schöner to imagine a second globe that represented the stars, which he did in another small text entitled, *Celestial Globe, or Use of Spheres of the Fixed Stars* (1533).[103] Very soon parallel globes soon became standard across Europe, as a host of globe makers, such as Gerard Mercator (1512-1594) and Willem Janszoon Blaeu (1571-1638) in the Netherlands, and Guillame Delisle (1675-1726) and Nicolas Bion (1652-1733) in France, adopted the practice.[104] Paired globes assumed the homogeneous space and liminal position that appeared in Book 12 of Euclid's work. They did so by putting viewers above the Earth and the celestial sphere, with both theoretically connected via a pole.[105] This perspective, akin to God's, was projected downward onto the globes and afforded the viewer a radically distant position that no terrestrial creature could attain.

Over the course of the seventeenth- and eighteenth centuries, globes became the most important means of diffusing human space. Globes themselves were increasingly produced and marketed for a larger public, including schools. On top of that, dozens of works on globes and their use appeared around Europe. Unfortunately, relatively few early-modern globes have survived, since they were usually discarded, after having become outdated. There are, however, plenty of examples of published guides to globes, including Robert Hues's *Treatise of Globes* (1627), published out of Amsterdam, W. Grant's *The Antiquity and Excellency of Globes* (1657), from

[102] Ibid. Chapter XII (unpaginated).
[103] Johannes Schöner, *Globi Stelliferi, Sive Sphaerae Stellarum fixarum usus, & explicationes, quibus quicquid de primo mobili demonstrari solet, id uniuersum prope continetur, Directionum autem ipsarum quas uocant, ratio accuratis, est exposita. Autore Ioanne Schonero Carolostadio, atque haec omnia multò quâm ante emendatiora & copiosiora singulari ac studio in lucem edita fuere Anno Christi M. D. XXXIII* (Norimbergae, 1533).
[104] Ibid. Dekker and Krogt, *Globes from the Western World*, Hess, "On Some Celestial Maps and Globes of the Sixteenth Century".
[105] See also John M. Headley, "Geography and Empire in the Late Renaissance. Botero's Assignment, Western Universalism and the Civilizing Process", *Renaissance Quarterly* 53 (2000).

London, and Robert de Vaugondy's *The Use of Globes* (1751), from Paris.[106]

Every early-modern work on globes reprises the conceptual structure within which the world became knowable. Consider figures 4 and 5, which come from a German guide to globes, published in 1791 and 1792. Figure 4 depicts a celestial sphere, and it comes from the frontispiece to part one of Johann Wolfgang Müller's *Instruction on the Understanding and Use of Artificial Celestial- and Terrestrial Globes...* (1791), a work marketed expressly to schools.[107] Published in Nuremberg, this book and its companion volume, whose frontispiece I consider below, served as manuals for the accompanying globes. In the center of the image is a celestial globe, around which lie the tools with which the globe can be properly oriented.[108]

The use of these tools represents how human space was inherently manipulable. In addition, the author was fully aware of the artificial nature of this process, as he noted that the globe is itself a fiction, since the stars are located at different distances from earth.[109] Now, I come down to Earth via Figure 5, which contains the frontispiece to part two of Müller's *Instruction*.[110] Here is the terrestrial sphere, which the text assumed to be at the center of the celestial one. As before, the user was expected to orient the object correctly, again using scientific instruments. More importantly, the text notes that this sphere was a fiction, too, since the earth is not a true sphere and the latitudinal and longitudinal lines were merely projections onto the earth from the sphere above, which as it happens did not exist either.[111]

The entire system of spatial orientation was wholly imagined and geometry was the foundation of this way of understanding space. Consider the images that surround the terrestrial globe in the center of Figure 5. On the left is a ship flying the Tricolor, thus, representing French exploration. In the middle is Australia, called Hollandia, which the Dutch only encountered in 1606 and the British first settled in 1788. To the right are British troops firing on indigenous people in Hawai'i, which is probably a reference to the misunderstanding that led to James Cook's death in 1776. Early-modern

106 W. Grant, *The antiquity & excellency of globes what a globe is, and of the circles without the globe, what the horizon is ... moreover of the circles which are described on the superficies of the globes ... all which are proper to the celestiall and terrestiall globes, with their uses* (London, 1657), Robert Hues, *Tractatus de globis coelesti et terrestri eorum que usu* (Amstelodami, 1627), Robert de Vaugondy, *Usages des globes celeste et terrestre faits par ordre du roy, par le S. Robert de Vaugondy, fils* (Paris, 1751).

107 Johann Wolfgang Müller, *Anweisung zur Kenntnis und dem Gebrauch der künstlichen Himmels- und Erdkugeln besonders in Rücksicht auf die neuesten nürnberger Globen, für die höhern Classen der Schulen und Liebhaber der Sphaerologie*, 2 vols., vol. 1 (Nuremberg, 1791).

108 Johann Wolfgang Müller, *Anweisung zur Kenntnis und dem Gebrauch der künstlichen Himmels- und Erdkugeln besonders in Rücksicht auf die neuesten nürnberger Globen, für die höhern Classen der Schulen und Liebhaber der Sphaerologie*, 2 vols., vol. 2 (Nuremberg, 1792).

109 Ibid. 2.

110 Ibid. 27-80.

111 Ibid. This point is especially clear in the chapter "Von der mathematischen Abtheilung der Erdoberfläche", Müller, *Anweisung zur Kenntnis, vol. II* 307-308. On the shape of the Earth, see Mary Terrall, *The Man Who Flattened the Earth: Maupertuis and the Sciences in the Enlightenment* (Chicago, 2002).

Germany had no colonial tradition, yet its spatial thinkers expressly injected the European colonial rivalry into their understanding of spaces and places that very few Germans would ever see. This approach is but a microcosm of a broader European agenda, as most people who lived in states that had colonies never saw more than maps or globes either.

In 1697, Gottfried Wilhelm Leibniz published *Nova Sinica*, which was a commentary on a series of Portuguese and Spanish travel reports on China. Leibniz had never left the Continent, but he felt perfectly secure in pronouncing on the virtues of Chinese society, one among which was its interest in geometry. Leibniz wrote:

> But there is no doubt that the monarch of the Chinese saw very plainly what in our part of the world Plato formerly taught, that no one can be educated in the mysteries of the sciences except through geometry.[112]

These lines reveal the essence of Euclidism's effect on early-modern systems of knowledge.[113] Regardless of what Leibniz had to say about China, he had the ability to project his own mind to places he could imagine, but had never seen. Without having been to China, he knew that the people who lived there were different from the people he saw every day. As many scholars have noted, Europeans have identified peoples by the spaces in which they believed "others" to live.[114] In the early-modern world stories brought back from the New World by Spanish explorers became the foundation for the noble savage myth. And for the modern world Edward Said has ascribed the construction of the "other" to systems of colonial exploitation, above all in the late eighteenth- and early nineteenth centuries. He holds that differences in power are the key to understanding the emergence of "otherness". This argument cannot be sustained.

At the end of the seventeenth century China and Europe were still rough equals, both in terms of cultural sophistication and economic development.[115] There was, thus, no asymmetricity on which "otherness" could be constructed. The roots of "otherness" extend much deeper than the colonial enterprises of the Asian peninsula that calls itself Europe.[116] The certitude with which the "other" was discussed was a product of Europe's long encounter with and cultivation of Euclidism. As Leibniz's work suggests Euclidian space allowed Europeans to produce images of peoples and places over which Europeans (then) had no dominion. The ability to imagine what no

[112] Gottfried Wilhelm Leibniz, *Writings on China*, Daniel J. Cook and Henry Rosemont trans. (Chicago, Ill., 1994). 50. Also quoted in John M. Headley, "The Universalizing Principle and Process: On the West's Intrinsic Commitment to a Global Context", *Journal of World History* 13 (2002): 291.

[113] Leibniz, *Writings on China*.

[114] Edward W. Said, *Orientalism*, Vintage Books ed. (New York, 1979).

[115] Kenneth Pomeranz, *The Great Divergence: Europe, China, and the Making of the Modern World Economy* (Princeton, NJ, 2000).

[116] Mary Louise Pratt, *Imperial Eyes: Travel Writing and Transculturation* (London, 1992).

one can see and, then, to apply this image is a peculiarly European virtue, or vice, depending on one's point of view.

The same certitude on matters of space is on display in the work of a one of Leibniz's contemporaries, Daniel Defoe. Many have read his most famous book, *Robinson Crusoe* (1719). Here, however, I concentrate on a much different text that Defoe published anonymously in the 1720s in *Applebee's Original Weekly Journal. In this text Defoe defended* himself against the charge of being uneducated, which had been leveled against him by a scholar. He wrote:

> In Geography and History he had all the world at his Finger's ends. He talked of the most distant countries with an inimitable exactness; and changing from one Place to another, the Company thought, of every Place or Country he named, that certainly he must have been born there. He knew not only where every Thing was, but what everybody did in every Part of the World; I mean, what Businesses, what Trade, what Manufacture, was carrying on in every Part of the World; and had the History of almost all the Nations of the World in his Head-*yet this Man was no Scholar*.[117]

Defoe's defense of himself highlights the spread of spatial knowledge through early-modern Europe. Although he had not studied at university, his mind hovered above the globe, putting things in their place. That his knowledge of the world's spaces and places was so exact is a reflection of both his career as a merchant and the enormous growth in the cultural production of spatial media, such as maps, globes, and travel reports. Unlike the scholar who maligned him, Defoe lived in human space and filled it with peoples and places.

Defoe's assessment of himself also suggests how much of European knowledge resulted from the sophisticated project of imagining space. Leibniz knew how to find China on a map and, had he been dropped anywhere into that realm, could no doubt have calculated his global position with reference to the stars. Of course, without a map, or more precisely, without local knowledge, his global positioning would not have done him much good. The central aspect of the revolution in spatial orientation that had occurred during the previous four centuries was the marriage of abstract constructions of space with the bits and pieces of knowledge that European explorers and travelers sent home in travel reports. The end result was a common image of a world filled with strange peoples and things, each of which had a place. This is the final result of Euclidism: without ever seeing the world Europeans could still put everything it contained into place.

[117] Quoted in William Minto, *Daniel Defoe* (New York, 1879). 5-6.

FIGURE 1. BILLINGSLEY, THE ELEMENTS (1570)

FIGURE 2. EUCLID, EVCLIDIS ELEMENTORVM LIBRI XV (1607)
(Removed image due to copyright)

FIGURE 3. JOHANNES SCHÖNER, OPUSCULUM GEOGRAPHICUM (1533)
(Removed image due to copyright)

FIGURE 4. MÜLLER, ANWEISUNG V. 1 (1791)
(Removed image due to copyright)

FIGURE 5. MÜLLER, ANWEISUNG, V.2 (1792)
(Removed image due to copyright)

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