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Beyond beauty : reexamining architectural proportion in the Basilicas of San Lorenzo and Santo Spirito in Florence

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5. Medieval Origins

The sets of proportions described in Chapters 2 and 3 have provided the first new impetus for progress in our understanding of the construction history of the basilica of San Lorenzo in many years. We have not yet exhausted the historical value of these new proportional discoveries, however. By providing new evidence of the design intentions of Matteo Dolfini and Filippo Brunelleschi when they made their successive contributions to the design of the basilica, these newly-identified sets of proportions now provide evidence highlighting two likely medieval precedents for important aspects of the designs of not only the basilica of San Lorenzo, but Santo Spirito as well.

5.1. The Lombard Connection

“...la sagrestia si tirò innanzi avanti a ogni altra cosa, e tirossi su di condizione, che la faceva stupire tutti gli uomini e della città e forestieri a cui accadeva el vederla, per la sua nuova foggia e bella. E concorrevavi continovamente tanta gente, che davano grandissima noia a chi vi lavorava.”¹

This account of the enthusiastic public reception of Filippo Brunelleschi's Old Sacristy as it reached completion in the late 1420s, even if perhaps embellished by Brunelleschi's admiring biographer to enhance the architect's reputation, is a remarkable record of the novelty and aesthetic appeal of Brunelleschi's early Renaissance style according to one later fifteenth-century resident of Florence.² Indeed, the account is not hard to believe, for the sacristy continues to be filled with admiring visitors today. The universal appeal of Brunelleschi's unique style has inspired many scholars to explore its formal origins. What precedents did Brunelleschi assemble as inspirational raw materials, and how did he meld them into such an artistically expressive and influential form of architecture?

Studies of the origins of Brunelleschi's style have, since the late nineteenth century, focused on two perceived characteristics of it. The first is the evident revival and synthesis of earlier architectural forms—though exactly what forms Brunelleschi revived and synthesized has been a matter of extensive discussion and evolving opinion. The second is the evident contrast in overall character between Brunelleschi's early Renaissance style and the Gothic style that preceded it, a quality that scholars often attribute in substantial part to Brunelleschi's purported use of mathematically rational and grid-based sets of architectural proportions.³ The present study expands this ongoing discussion by examining some new possible design precedents for the basilicas of San Lorenzo and Santo Spirito that have never before been considered in this context. It furthermore

expands this discussion by accepting the likelihood that Brunelleschi based much of his design for the San Lorenzo/Old Sacristy complex, including including its sets of proportions, on an earlier, partially-executed design by the church prior Matteo Dolfini.⁴ It therefore considers the possibility that both Dolfini and Brunelleschi might have brought certain design influences from earlier buildings into the present San Lorenzo design. This study, furthermore, benefits from a new approach to the problem of sets of architectural proportions in the works of Brunelleschi.

Most of the design precedents newly proposed in this study have come to my attention as indirect products of my previous studies of the sets of proportions found in the basilicas of San Lorenzo and Santo Spirito in Florence.⁵ Those studies consider sets of architectural proportions to be genuine historical artifacts that cannot, due to the nature of such sets, have had any significant influence on architectural appearances.⁶ The present study builds upon that assumption by using the sets of proportions found in the basilica of San Lorenzo as a non-visual primary source that can call attention to promising new architectural comparisons. Once those comparisons are identified, the visual evidence in the comparisons themselves carries the weight of the argument. In this way, our attention is drawn to a northern region that scholars have not previously considered as a possible source of significant design influence on the seminal works of Florentine early Renaissance architecture.

Brunelleschi the Synthesizer

One of the earliest and most widespread scholarly views of Brunelleschi found in the literature frames the architect as the one singlehandedly responsible for the *renovatio* of ancient Roman architectural forms and principles following a pejorative Gothic interlude. This view has reached us, by way of the scholarship of the late nineteenth and early twentieth centuries, from Giorgio Vasari's sixteenth-century *Le Vite*, and ultimately from one of Vasari's own sources, the fifteenth-century *Vita* of Antonio di Tuccio Manetti.⁷ Manetti furthermore notes that Brunelleschi sought to revive not only the Romans' way of building, but "[...] le loro proporzioni musicali [...]."⁸ Ever since Carl von Stegmann and Heinrich von Geymüller attempted to identify modular proportions in the Basilica of San Lorenzo in 1883, and especially since the appearance of Rudolf Wittkower's article "Brunelleschi and 'Proportion in Perspective'" in 1953, many scholars have adopted the view, closely related to the above-noted one, of Brunelleschi as the architect of "metrical coherence"; a view that assumes that pre-Brunelleschi medieval architecture was not metrically coherent.⁹

A dissenting nineteenth-century view, introduced by Dehio and inspired by a different reading of Vasari, proposes another kind of *renovatio* as Brunelleschi's main design interest: the revival of classicizing Tuscan Romanesque style forms, to the exclusion of ancient Roman forms.¹⁰

This theme is further developed by Fontana, who insists that Brunelleschi conceived his style not “...in Roma sugli esemplari classici, bensì in Firenze ed altrove su fabbriche medioevali di carattere romanico...”.¹¹ Most recent scholarship (i.e., that produced by living scholars) has continued to explore this medieval Tuscan theme, while also broadening the scope of investigation to include extra-Tuscan sources, and reconsidering the question of possible Roman influences. Thus, while Hoffman and Horster have reexamined the ancient Roman theme in relation to Brunelleschi’s work, Bruschi, Burns, Klotz, Murray, Saalman, Schedler and Trachtenberg have explored possible Tuscan Romanesque and *trecento* Tuscan Gothic influences. Burns and Bruschi furthermore note certain relationships between Brunelleschi’s buildings and architectural depictions in *trecento* frescoes.¹²

Looking beyond both Rome and Tuscany, Burns notes the striking formal and documentary links between the Old Sacristy of San Lorenzo and the Romanesque Baptistery of Padua Cathedral, in addition to other possible connections between works attributed to Brunelleschi and medieval buildings in Venice and the Veneto.¹³ Elaborating upon the observations of Fabriczy, Fontana and Burns, Hyman illuminates a wide range of stylistic and structural affinities between the works of Brunelleschi and “eastern Early Christian, Venetian and Byzantine, Persian and Islamic structures.”¹⁴ Trachtenberg later explores possible Byzantine connections in more detail.¹⁵ These Eastern explorations are of particular interest in light of Sanpaolesi’s ambitious and well-documented comparison between Brunelleschi’s cupola of the Cathedral of Florence and the massive, double-shelled, pointed dome of herringbone brickwork enclosing the mausoleum of Ilkhan Ulghaitu in Soltanieh, Iran (1304-1312).¹⁶

Following its demotion in most Brunelleschi literature in favor of attention to Tuscan and other sources, Roman civilization has recently reentered broad scholarly discussion of Brunelleschi’s possible influences. While Hyman proposes that Brunelleschi may have derived much of his classicism from the Early Christian basilicas of Ravenna, Lavin draws connections between the Brunelleschi basilicas and the Early Christian basilicas of Rome itself, as does Trachtenberg, who argues that Brunelleschi’s references to the Early Christian basilica were consistent with the medieval Roman tradition of recreation of that building type; an argument that brings us back to the question of ancient Rome.¹⁷ Which Rome, if either, did Brunelleschi reference?

Believing that Brunelleschi’s work betrays no evidence of direct quotation from ancient Roman architecture, some scholars embrace an extreme position of total Brunelleschi-in-Rome denial: the belief that Brunelleschi was not only not influenced by Roman architecture, but that he never set foot in the city.¹⁸ This position, however, has much contrary evidence to contend with. There is, for example, the small figure of the *spinario* in Brunelleschi’s bronze competition panel of 1401, which is but a clothed and mirror-image replica of the famous Roman statue that may have

been displayed outside the Lateran basilica in Brunelleschi's day.¹⁹ There are, furthermore, the Cathedral of Orvieto's projecting semi-cylindrical chapels, slit by tall round-headed windows, that are strikingly similar to those of Brunelleschi's Basilica of Santo Spirito as originally planned.²⁰ Located between Florence and Rome, Orvieto and its impressive medieval cathedral would have been a convenient and rewarding rest stop for fifteenth-century artists travelling between the two cities (Figure 5-1), which is exactly what Vasari tells us Donatello once used it for.²¹ Finally, there is the continual traffic that flowed between Florence and Rome in Brunelleschi's day.

Even if one chooses to reject Manetti's claim that Brunelleschi lived in Rome between about 1409 (or earlier) and 1419 and made numerous trips to Florence, the claim itself indicates that such extensive travel between the two cities was physically and culturally possible in the fifteenth century, at least for persons of sufficient stamina and means.²² We may similarly interpret Vasari's note that Brunelleschi once trudged off from Florence to Cortona (about one-third of the way to Rome) to examine a Roman sarcophagus and returned before anyone realized he had gone.²³ In 1434 Brunelleschi's adoptive son, il Buggiano, absconded all the way to Naples with his master's money and jewels, and was returned to Florence only after the Pope, at Brunelleschi's urging, issued a bull entreating the Queen of Naples to intervene.²⁴ Thus Trachtenberg is indeed justified in declaring that "[...] the burden of proof falls on those who would *deny* Rome to Brunelleschi [...]."²⁵

Burns demonstrates that there is no contradiction in observing the evident lack of direct quotation from antique Roman sources in Brunelleschi's work while also accepting the likelihood that Brunelleschi spent extensive time in Rome. He thus reconciles his statements that "[...] Brunelleschi is the true reviver of much of the spirit of ancient architecture" and "[...] there is not a single major work of Brunelleschi for which a plausible and specific post-antique source (or sources) cannot be suggested", by arguing that "the idea of antique architecture as a set of principles, rather than precedents, is implicit in Brunelleschi's buildings [...]."²⁶ Indeed, Brunelleschi's stylistic synthesis, no mere cut-and-paste collage, requires of us an alertness to principle as well as precedent, and an acknowledgement of the important role travel played in satisfying Brunelleschi's voracious curiosity about art and architecture.²⁷

In light of the preceding discussion, we must assume that Brunelleschi was open to learning from both Romes, pagan and Christian, and similarly both Florences (in light of his probable belief that the Baptistry of Florence was Roman), along with many other sources of architectural inspiration. Thus, in accordance with this view of Brunelleschi's style as the product of wide ranging design synthesis, Trachtenberg notes that for Brunelleschi, "the past, Roman and otherwise, was [...]" a vast landscape of architectural resources that he selectively mined for highly original purposes."²⁸ A map highlighting Brunelleschi's possible source locations referred to thus far (and a few more to

be discussed below) reveals the impressive geographical range of his apparent design synthesis (Figure 5-1). It also reveals a curious gap. Tuscany, Rome, the Veneto, and the East contained a diverse wealth of architectural forms from the years preceding Brunelleschi's lifetime, but what about the major architectural activity underway *during* his lifetime?

Construction of the Cathedral of Florence up to the tambour served as the primary backdrop of architectural construction activity to Brunelleschi's childhood and young adulthood, and both Brunelleschi and his father served on various citizen construction committees associated with it.²⁹ Studies examining certain similarities between the Cathedral of Florence and the buildings of Brunelleschi have been cited above, but given the stylistic gulf that separates the cathedral from Brunelleschi's early Renaissance style, the former hardly seems to have provided a significant source of inspiration for the latter. Furthermore, before Brunelleschi's own activities turned the cathedral cupola project into an architectural laboratory that drew, according to Manetti, "[...] masters, architects, masons, and master engineers from all of Christendom [...]," construction of the cathedral appears to have been primarily of local interest, involving little if any architectural innovation of note.³⁰ The same cannot be said of architectural activity in Lombardy during the late fourteenth and early fifteenth centuries.

Lombard Architectural Innovations

In 1386 the Cathedral of Milan was founded, an event that symbolized the cultural and economic resurgence of Lombardy under the leadership of Gian Galeazzo Visconti (ruled 1378-1402). The scale and structural ambition of the Duke's proposed new cathedral exceeded the capabilities of the Lombard masons and, apparently, the technical complexity of the Cathedral of Florence before the cupola became the main focus of attention. Milanese officials thus organized convocations of master masons, engineers, and other experts from Italy and north of the Alps in 1392, 1400, 1401 and later to resolve significant technical issues. So impressive was this architectural activity in Milan that in 1390 the *comune* of Bologna sent the architect Antonio di Vincenzo to study the nascent Cathedral of Milan pursuant to its own ambitious project for the great civic Basilica of San Petronio.³¹ Antonio was probably just one of numerous architectural pilgrims who made their way to Milan and other Lombard cities during the late fourteenth and early fifteenth centuries to study this cathedral and several other major works. Brunelleschi (1377-1446) came of age during this period of Lombard distinction in Italian architecture and, trained as a goldsmith at a time when goldsmiths and other artists and artisans were frequently called upon as advisers on architectural matters, he surely kept abreast of architectural developments in Lombardy and elsewhere. Indeed, long before he became *capomaestro* Brunelleschi served as an adviser to the

Opera of the Cathedral of Florence in 1404, and perhaps later to the *Opera* of the Cathedral of Milan as well.³² The sixteenth-century chronicler Antonio Billi notes one trip by Brunelleschi to Milan (possibly datable to about 1420, if indeed it occurred) at the invitation of Filippo Maria Visconti to advise on the construction of a fortress.³³ That Brunelleschi respected the construction prowess of the Lombards, even while evidently serving as an advisor to them, is implied in Manetti's report that as *capomaestro* of the Florentine cupola he broke a strike of construction workers by hiring "[...] 8 lombardi [...]" perhaps in reference to the supervising master masons who Manetti notes were assigned one to each side of the octagonal structure.³⁴ Brunelleschi's apparent respect for contemporary Lombard architecture also helps to explain his reaction to an alteration that according to Manetti he was compelled to make to his predecessor's design for the Basilica of San Lorenzo.

In about 1480 Giuliano da Sangallo, a follower and younger contemporary of Brunelleschi, made a sketch that shows the floor plan of the Basilica of San Lorenzo much as it appears today, but lined with nave chapels twice as deep as the present ones (Figure 3-5).³⁵ Earlier in this study I have provided new evidence that Giuliano's deep nave chapels in this sketch not only reflect Brunelleschi's preferred San Lorenzo design, but the one he inherited from Dolfini (Figures 3-16 and 4-15).³⁶ According to Manetti, when Brunelleschi took over the project around 1421, probably at Dolfini's death, he removed these nave chapels on the orders of Giovanni de' Medici who, Manetti claims, had patron-like authority over the project. Giovanni did so, Manetti continues, because he was unable to find enough citizens willing to build them. According to Manetti Brunelleschi did so "[...] malvolentieri, perché la gli pareva cosa misera [...]"³⁷ Manetti apparently shared Brunelleschi's favorable opinion of Dolfini's chapels, for he laments that "[...] 'l corpo della chiesa dalla croce in giù, che non è conforme alla detta croce [...]"', an apparent indication that the *present* nave chapels, built after 1457, are not as deep and as tall as Brunelleschi, following Dolfini, intended.³⁸ Dolfini's deep nave-chapel scheme appears to have been quite progressive for its day.

The two rows of deep nave chapels in Dolfini's plan transform the conventional Latin Cross medieval basilica type from a cruciform building in space, to a rectangular block from which is carved a cruciform negative space (Figure 3-16). They also provide an elegant solution to the increasing demand in late medieval urban culture for family chapels by a growing class of merchant patricians.³⁹ This spatial and social transformation of the basilica building type had previously appeared in Florence in the late fourteenth-century reconstruction of the Basilica of Santa Trinita, though this small, dimensionally irregular church hardly seems architecturally compelling enough to have served as the model for the first major basilica to be initiated in Florence in over a century (Figure 5-2). It lacks the confident geometrical clarity of Dolfini's San Lorenzo scheme, perhaps due to its severe site constraints, and provides an unremarkable interior experience.⁴⁰ The existence of a

common source for both basilicas seems more likely. Manetti's note that Dolfini began his project "[...] di pilastri di mattoni [...]" offers a possible hint that the source might not have been Florentine.⁴¹ Brick was an unusual primary building material in medieval Florence, but common in the north.⁴² Indeed, in Dolfini's day the largest basilica construction project underway near Florence was Antonio di Vincenzo's aforementioned Basilica of San Petronio in Bologna, which is built entirely of brick. The enormous basilica that we see today was originally intended to constitute just the nave of an even larger cruciform structure, and Florentine architects must have been familiar with the project.⁴³ It displays a modular, deep nave chapel scheme very similar to that of Dolfini's San Lorenzo, the only significant difference between them being the elimination of alternate nave piers in the Bologna basilica (Figure 5-3), where the Dolfini/Brunelleschi plan has uninterrupted rows of point supports (Figure 3-16).⁴⁴ The deep nave chapel scheme, however, does not appear to have originated with Antonio either.

The drawings that Antonio di Vincenzo made in 1390 provide a record of the projected design of the Cathedral of Milan just four years after groundbreaking and indicate that the design of the Basilica of San Petronio owes a significant debt to it, particularly in the way the cross-section rises from a five-bay-wide nave.⁴⁵ Other aspects of the Bologna design indicate, however, that while Antonio may have been sent to Milan to examine the cathedral works, he came home equally impressed by another basilica under construction nearby. Architectural pilgrims from central Italy who made their way to Milan during the late fourteenth and early fifteenth centuries would have been sure to visit Pavia, just 35 kilometers to the south (Figure 5-1). Pavia boasted numerous impressive Romanesque churches harking to the city's past distinction as capital of the Longobard kingdom (7th to 12th centuries), and several major new works attesting to the city's then-current distinction as the seat of the powerful Visconti dukedom.⁴⁶ The most impressive of the new works were designed by the Visconti court architect, Bernardo da Venezia.⁴⁷ These works include the Castello di Pavia (the duke's residence), begun c. 1370 under Galeazzo II Visconti (ruled 1354–1378); the basilica of Santa Maria del Carmine in Pavia, begun c. 1373; and the Certosa of Pavia, a vast monastic complex begun in 1396 under Gian Galeazzo Visconti to house the ducal tombs.⁴⁸ One of these works appears to have attracted the sustained attention of the architectural community of northern and central Italy for many decades after its first vaults began to rise.

The Basilica of Santa Maria del Carmine in Pavia is a compact yet imposing basilica, characterized on the outside by a low, broad, box-like form, and on the inside by weighty, closely spaced clusters of brick columns, colonnettes, and piers (Figure 5-4). The blunt, curving surfaces of the engaged columns and cushion capitals of the minor order, the restrained use of ornament (confined to the major order column capitals), the slightly pointed arches of varying sizes, and the

lucid geometrical logic throughout create a unique spatial experience that conveys seemingly contradictory impressions of strength, solidity, and lightness. From certain vantage points the basilica appears to have been carved from a living mountain of brick. From others it appears strangely ephemeral, its upper regions dematerialized by blank expanses of smooth white plaster. Much of this emotive impact of the design comes from an aspect of regulation and discipline that seems driven by a latent but deliberate classicism.

Comparison of the repeating interior elevations of the Santa Maria del Carmine and San Petronio nave bays suggests that Antonio admired the forceful and compositionally efficient design of the Carmine bays, and copied it directly. He appears to have merely increased the bay width slightly relative to its height, enlarged the oculus, and modified the forms of the pier shafts and capitals perhaps based on those of the Cathedral of Florence (Figures 5-5 and 5-6).⁴⁹ Antonio's admiration for the Carmine of Pavia may have stemmed in part from his ability to observe a substantial portion of it already standing. At the time of his visit to the Cathedral of Milan, after all, there was little to observe but some unfinished foundations, tentative intentions, and a host of rancor.⁵⁰ The Carmine of Pavia, by contrast, about seventeen years into construction under the direction of a single, politically powerful architect, was probably already displaying imposing vaulted spaces.

Floor plan comparisons suggest that the Carmine may have served not only as the source of Antonio's deep nave chapel scheme (Figures 5-3 and 5-7), but more significant for this investigation, as the model for Dolfini's entire San Lorenzo floor plan, not including the double chapels at the ends of the transept (Figures 3-16 and 5-7).⁵¹ While we have no information regarding the shapes and sizes of the nave piers or columns that Dolfini intended for his San Lorenzo design before Brunelleschi turned them into monolithic columns of *pietra serena*, and while my comprehensive survey of the Carmine floor plan has thus far revealed no significant proportional similarities with my reconstructed Dolfini floor plan, the two plans are nevertheless schematically virtually identical.⁵² With appendages removed, as shown in Figures 3-16 and 5-7, both consist of rectangular perimeters broken only by square high altar chapels; both have four transept chapels and sixteen nave chapels, all identical; both contain cruciform spines conceptually composed of eight large squares, one each for the crossing square, high altar chapel and each transept arm, and four for the nave; and both are based on a conceptual module corresponding to one of these large bays—let us say the crossing square—in which could fit four of the chapels, approximately if not exactly.

Antonio di Vincenzo's and Matteo Dolfini's apparent interests in the designs of the Cathedral of Milan and the Carmine of Pavia anticipated Brunelleschi's own apparent architectural investigations in Lombardy. The Basilica of Santo Spirito (Figure 5-8) and the Cathedral of Milan

(Figure 5-9), although dissimilar in scale and style, share several fundamental characteristics. In plan, both have rows of freestanding columns arranged on regular grids on center—an 11 br. grid at Santo Spirito and 16 br. at the Cathedral of Milan—that are echoed by peripheral rows of identical engaged columns.⁵³ In both buildings these columnar arrays create impressions of freestanding, hypostyle hall-like skeletal structures that resemble formerly open-air pavilions that have seemingly been enclosed by walls only due to functional necessity. Perhaps most significant, both have such similar numbers and arrangements of bays, columns and engaged columns that the Cathedral of Milan floor plan, with a few minor modifications, could have served as the template for the simplified and more regularized Basilica of Santo Spirito floor plan.⁵⁴

If we imagine the outermost side aisles of the Cathedral of Milan nave divided up into chapels—as appears to have been originally intended (see below)—then both this basilica and that of Santo Spirito would have three-bay wide naves, transept arms, and apses, the outermost bays of which form continuous ambulatories that lead worshippers in from either side door in the façade, down the aisle, around the transept and apse, and out through the other aisle. Furthermore, counting outwardly from the crossing piers, both basilicas have nine-bay long naves, three-bay long transept arms; and, if we exclude the canted end of the Cathedral of Milan apse, three-bay long apse-like projections as well. The preceding observations point more strongly toward the Cathedral of Milan as the primary source of inspiration for the Santo Spirito floor plan than the more proximate Cathedral of Pisa, which features a similar extended ambulatory but entirely different numbers and arrangements of bays.⁵⁵ While Brunelleschi may have studied the projected design for the Cathedral of Milan, however, like Antonio di Vincenzo before him he appears to have returned home particularly impressed by the interior of the Carmine of Pavia, and well versed in its details.

One of the most memorable features of the securely attributed Basilica of Santo Spirito is the surreally foreshortened vista that greets visitors upon entering either the left or right façade portal (Figure 5-10).⁵⁶ On one side of each aisle, the columns appear to touch one another forming an apparently solid yet diaphanous wall. On the other, engaged columns appear closely packed together, separated only by complex moldings resembling rubbery, compressed gaskets. When similarly viewed down either of the aisles, the Carmine of Pavia appears to be virtually a brick version of the Basilica of Santo Spirito (Figure 5-11). In the Carmine, rows of classically proportioned engaged columns appear tightly packed together, separated only by forms resembling rubbery, compressed gaskets. Here, however, the gasket-like forms occur on both sides of each aisle, and consist of clusters of attenuated colonnettes. Perhaps Brunelleschi even took measurements of the Carmine column diameters and intercolumniations, for their dimensions are very similar to those of Santo Spirito (Figures 5-7 and 6-8, dimensional annotations).⁵⁷

Since the visual evidence presented here places Brunelleschi at the end of one of the aisles in the Santa Maria del Carmine nave, carefully studying the striking effect of one-point perspective and quite possibly recording measurements to further his investigation, we might reasonably propose that the Carmine contributed to Brunelleschi's research pertaining to his eventual development of scientific perspective drawing techniques. Indeed, some influence of the Carmine may be detectable in Masaccio's *Trinity* fresco in the basilica of Santa Maria Novella in Florence, a project on which Brunelleschi very likely collaborated.⁵⁸ In that fresco, small Doric columns serve as visual gaskets that separate pairs of Ionic columns in the foreground and background (Figure 5-12, middle column). The resultant clusters of three columns visible on each side of the central barrel vault appear tightly packed together in perspectival compression, much like the engaged columns and colonnettes of the Carmine of Pavia, and the engaged columns and complex molding strips of Santo Spirito (Figures 5-10 and 6-11). Perhaps Brunelleschi considered these little intermediate Doric columns in the *Trinity* to be necessary devices for leading the eye into perspectival space, after having first observed a similar effect in three-dimensions at the Carmine.

Another hallmark feature of the Basilica of Santo Spirito that is prefigured in the Carmine is the union of the first step leading into the chapels with the plinths of the engaged columns standing between the chapels (Figure 5-13). Following Saalman, scholars typically attribute this elegant device to Brunelleschi, but we now see that Bernardo used it first in the Carmine (Figure 5-14).⁵⁹

The visual evidence presented above regarding deep nave chapels, nave bay interior elevations, foreshortened aisle views, and plinth/step unions suggests that the Carmine of Pavia exerted a substantial influence on an impressive array of late fourteenth and early fifteenth-century basilicas outside of Pavia, including the Basilicas of San Petronio in Bologna; and Santa Trinita, San Lorenzo and Santo Spirito in Florence. Other possible Carmine-inspired basilicas, recognizable by their modular layouts and signature rows of deep nave chapels, perhaps include two more works of Bernardo da Venezia: the Certosa of Pavia, which according to Ackerman's reconstruction originally was to include deep nave chapels, and the basilica of Santa Maria del Carmine in Milan (founded c. 1400).⁶⁰ Later deep nave-chapel basilicas that perhaps belong to this lineage include those of Santa Maria delle Grazie in Milan (begun by Giuniforte Solari in 1463), San Francesco in Ferrara (begun c. 1470), and San Salvatore in Padua (begun c. 1460).⁶¹

The list of Carmine-influenced basilicas should perhaps also include the Cathedral of Milan which, as noted above, was originally planned with deep nave chapels in place of the outermost side aisles (Figure 5-9). By 1391, after the foundations for at least a portion of these nave chapels had been completed, the chapels were removed from the design. In 1400 Bernardo da Venezia and a collaborator, Bartolino da Novara, petitioned Duke Gian Galeazzo Visconti for their reinstatement.

Although the petition was unsuccessful, it illuminates some contemporary arguments in favor of this innovative and influential chapel scheme. The architects' first argument is iconographical: through this modification, they claim, "[...] se porave vedere el corpo de Cristo [...]," in other words, one would perceive the shape of the cross in the interior void thus created. Their second argument is structural: The deep nave chapels "[...] vegniarevese a dare grandissima forteza ale altre tre nave [i.e., the central nave and two side aisles] per quilli archi butanti avereve più fermo [...]," in other words, the chapel walls would serve as buttresses to support the vaulted nave and aisles.⁶²

These contemporary observations, combined with the observations presented above, indicate that the remarkable basilica of Santa Maria del Carmine of Pavia appears to have introduced social, spatial, experiential, optical, iconographical, structural and classical ornamental innovations into late fourteenth and early fifteenth century architectural culture. To this list may now perhaps be added a stylistic innovation that may be particularly relevant to our research into the sources of Brunelleschi's early Renaissance style.

Regional Romanesque Revivals

In the Carmine of Pavia Bernardo presents a highly disciplined Lombard Romanesque style that is analogous to Brunelleschi's own unique style, which is essentially Tuscan Romanesque in architectural vocabulary and found its first complete expression half a century later in the design of the Basilica of San Lorenzo in Florence. A seemingly conscious revivalist tendency in the Carmine becomes apparent through comparison with the small Romanesque abbey church of Cerreto in Lodi, which Romanini identifies as its likely model (Figures 5-4 and 5-15).⁶³ In addition to their floor plans based on cruciform arrangements of eight large square modules—that of the Carmine lined with deep nave chapels, that of Cerreto lacking nave chapels—both churches share Romanesque features such as robust columns with cushion capitals, rudimentary ogival cross-vault ribs, and plain archivolts that are semi-circular at Cerreto, and only slightly pointed in the Carmine.⁶⁴

Of particular note, however, is not merely the reuse of outmoded forms, but the apparent deliberateness with which Bernardo has refined and regularized them, replacing Romanesque improvisation with a rigorous code of classical consistency and rationality. Gone, for example, are the gravity-defying, engaged corbelled columns of the Cerreto nave that taper, contrary to classical norms, from top to bottom, and the ambiguous surfaces to which they are attached that transmogrify from massive piers to delicate colonnettes (Figure 5-15). In their places appear various standardized columns of a distinctly classical character (Figure 5-4). Bernardo even demonstrates an understanding of antique superposition: at Cerreto all column capitals are identical (Figure 5-15); in the Carmine of Pavia the major order has Corinthian-like capitals, in notable contrast to the Doric-

like cushion capitals of the minor order (Figure 5-4). Even more remarkable is Bernardo's use of the double-scutia column base, an uncommon feature in Lombardy that implies direct knowledge of ancient Roman works (Figures 5-14 and 5-16).⁶⁵

Just as Bernardo, at the Carmine, rationalized and in some cases quite specifically Romanized the forms of the Lombard Romanesque style, so too did Brunelleschi, at San Lorenzo and Santo Spirito, dispense with the polygonal column shafts, irregular arches, and exuberant polychromy that characterize his apparent Tuscan Romanesque sources such as the exterior arcades of the Baptistry of Florence, in favor of, in the words of Saalman, "reduction and regularization of forms and the absolute uniformity of identical details."⁶⁶ For example, he did not merely borrow the entablature blocks of the aforementioned Baptistry arcades (and perhaps those of other works such as the Badia of Fiesole facade) down to the smallest detail, but elevated their status from autonomous elements of surface decoration to integral components of rationalized and comprehensive minor order entablature systems (Figure 5-10).⁶⁷ As in the Carmine of Pavia, in the Basilicas of San Lorenzo and Santo Spirito structural members (whether actually structural or merely expressions of structure) are set off by white plaster walls that do not appear to have ever been intended to be frescoed. The overall result is a monumentality and regularity that is distinctly Roman in character, if Romanesque in vocabulary.

Manetti's description of Brunelleschi's particular brand of classicism as "[...] alla romana ed alla antica [...]," together with his accounts of Brunelleschi's Roman sojourn, indicate that at least one fifteenth-century observer believed that Brunelleschi was driven by a conscious revivalist impulse, even if the evidence presented above indicates that this impulse was not limited to Roman sources.⁶⁸ Would it be correct to interpret Bernardo's classicism at the Carmine of Pavia in a similar revivalist light? Would this Lombard building best be described as an example of a "[...] provincial Gothic ecclesiastical style [...]," as does Ackerman in his 1949 article "The Certosa of Pavia and The Renaissance in Milan," or as an early example of what Ackerman later in the same article describes as "[...] the strange phenomenon of the Romanesque revival [...]" which he proposes "[...] as the leitmotif of the Milanese Renaissance"?⁶⁹ Thus, does Bernardo's classicism constitute Survival or Revival of Romanesque forms?⁷⁰ Although we lack commentary from a contemporary Lombard observer comparable to Manetti, the preceding discussion would seem to suggest that both interpretations may be equally valid.

The chief characteristics of the style of the Carmine of Pavia, according to Ackerman, are "first, that this Lombard Gothic has ignored thirteenth and fourteenth century developments elsewhere, and second, that it is none the less truly Gothic, and not a sub-Romanesque vestige."⁷¹ Yet the style of the Carmine would also seem to be consistent with Ackerman's description of the

Milanese Renaissance style that emerged nearly a century later. Driving the adoption of the Lombard Romanesque revival by Milanese patrons and architects in the mid- to late-fifteenth century, Ackerman proposes, were four factors: 1) the intense regionalism of Lombard architects, 2) “[...] the impressive effects of massing and interior space [...]” that the Romanesque style provided, 3) the “non-Gothic” character of the Romanesque style, which made it modern in the Renaissance sense, and 4) the belief that the Romanesque style was “[...] the stepping stone to Rome, and as such enjoyed high repute.”⁷² Indeed, the same four factors might also explain not only the Romanesque features of the Carmine of Pavia, but the Tuscan Romanesque features of Brunelleschi’s works in Florence.

Conclusion to the Lombard Connection

If Bernardo da Venezia’s Lombard Romanesque-inflected style in the Carmine of Pavia is the product of a conscious revival and refinement of regional Romanesque forms, it would constitute a particularly provocative precedent for our study of Brunelleschi’s Tuscan Romanesque-inflected style, for it would raise the question of whether or not Brunelleschi understood the style of the Carmine to be a conscious Romanesque revival. If he did, it would raise the additional question of whether Brunelleschi borrowed this revivalist impulse from the Carmine, as he appears to have borrowed other ideas; or conversely, whether his own Tuscan Romanesque revival constituted a similar yet independent development half a century later. Scholars have identified other examples of Romanesque revivals in northern Europe from the late fourteenth to the early sixteenth centuries, but those of Bernardo and Brunelleschi are distinguished by their highly disciplined, Romanizing classicism.⁷³

This comparison between Bernardo’s and Brunelleschi’s revivalist styles is, of course, a limited one due to the obvious differences of appearance between them. While each may be interpreted as a “stepping stone to Rome”, due to its refinements of its respective regional Romanesque style forms, Brunelleschi’s appears, at least outwardly, to lead more directly to Rome than Bernardo’s. Not only does the Tuscan Romanesque style look more Roman than the Lombard Romanesque, but Brunelleschi’s use of monochromatic *pietra serena* for all structural articulations imbues his buildings with a marble-like austerity that reinforces the Roman resemblance (Figures 5-10 and 5-11).⁷⁴ These characteristics made Brunelleschi’s style an effective conduit to the revival of the supra-regional architecture of ancient Rome initiated by the next generation of architects, including Giuliano da Sangallo, Alberti, and Bramante—a revival that may be considered the essential characteristic of Renaissance architecture.

Whether or not Bernardo da Venezia's revivalist impulse helped to inspire Brunelleschi's similar impulse—and thus indirectly influenced the development of the Renaissance style of subsequent generations—is too complex a question to be answered given the current state of knowledge about late medieval Lombard architecture and its fifteenth century dissemination. As for the particular characteristics of Brunelleschi's style itself, however, a decisive Lombard influence seems undeniable in light of the evidence presented in this study. Previous scholars have viewed Lombardy as the *recipient* of early Renaissance architectural influence from Florence, through the work of Filarete and others beginning in the mid-fifteenth century. We now see that the influence appears to have been mutual, and to have begun when Brunelleschi, and probably Dolfini before him, looked to Lombardy as a source of architectural design innovation.

In addition to the apparent Lombard influences considered here, the design of the basilica of San Lorenzo also exhibits influences of medieval buildings in Florence. Brunelleschi, for example, appears to have drawn inspiration from the blind arcades of the Baptistery of Florence in his design of the San Lorenzo nave arcade bays. Furthermore, whoever designed the set of proportions embedded in the dimensions of the latter—i.e., Dolfini or Brunelleschi; in Chapters 2 and 4 I have argued that it was more likely Dolfini—appears to have drawn proportional raw materials from the nave arcade bays of the basilica of Santa Maria del Fiore (the Cathedral of Florence) with which to begin.

5.2 Santa Maria del Fiore

In Chapter 2, I identified a subtle and complex set of proportions in the San Lorenzo nave arcade bays that contains distinct layers of significance related to late medieval geometry, number theory and arithmetic.⁷⁵ That study reveals features never before metrically documented in the study of medieval or Renaissance architectural proportion, including key dimensions determined plinth to plinth, the use of fractions as both numerical and graphic devices, and the use of number pairs (both whole and fractional) to closely approximate geometrically-derived, mathematically irrational ratios (Figure 4-12). Scholars typically single out the proportions of the Basilica of San Lorenzo as marking a turning point in the history of architecture—a “radical departure,” according to one popular textbook, from medieval precedent.⁷⁶ It is a claim, however, based on *prima facie* impressions, for prior to my study no one knew what the proportions of that basilica are because no one had ever studied them based on accurate, comprehensive and verifiable measurements.⁷⁷ Ultimately the claim is an attempt to attribute a perceived difference in overall visual character between medieval and Renaissance architecture to systematic, orderly and mathematically rational sets of proportions; sets that are purportedly present in Renaissance architecture (of which San

Lorenzo is taken as an archetypal example) but not medieval.⁷⁸ My recent study constitutes one step toward correcting this misconception, for it shows that every aspect of the set of proportions found in the basilica of San Lorenzo is thoroughly consistent with late medieval knowledge and practice. My attribution of that set of proportions to Matteo Dolfini constitutes another step, for Dolfini, the prior-architect who preceded Brunelleschi as *capomaestro* of the basilica reconstruction and who lived most of his life during the fourteenth century, can hardly be considered a Renaissance figure.⁷⁹ A third step is now to identify similarities between that set of proportions and those of medieval buildings.

One particularly prominent medieval structure that has a set of proportions that bears notable similarities to the San Lorenzo nave arcade bay set of proportions is the nave of the basilica of Santa Maria del Fiore. The similarities in these sets of proportions suggest not only that the former is most productively studied in a medieval context, but that Dolfini may have borrowed specific parts of the Santa Maria del Fiore set of proportions for use in the design process that ultimately led him to the San Lorenzo set of proportions. The nave arcades of the Basilica of Santa Maria del Fiore make promising subjects for a study of architectural proportion because they are composed of repeated bays with logical subdivisions (Figure 5-17), and because surviving documents record discussions within the cathedral *Opera* about the design and dimensions of those bays.⁸⁰

We may assume that every detail of this prominent, publicly-financed construction project was closely studied by all architects and aspiring architects of note in late fourteenth-century Florence, including Dolfini. Thus, a study of the Santa Maria del Fiore proportions is likely to yield valuable insights into architectural practices that were current when Dolfini designed the San Lorenzo set of proportions. This study is in two parts: Part I describes what appears to be the set of proportions, or a part thereof, that architect Francesco Talenti designed for the Santa Maria del Fiore nave arcades, with the approval of the cathedral *Opera*. Part II explores the mathematical knowledge and attitudes toward quantification in fourteenth-century Florence that constitute necessary historical context for a correct reading of that set of proportions.

A Proposed Nave Arcade Bay Set of Proportions

The four-bay nave of the Basilica of Santa Maria del Fiore is defined by eight large, slightly pointed arches supported by piers that appear to be evenly spaced (Figures 5-17 and 5-18).⁸¹ Indeed Bernardo Sansone Sgrilli, in his detailed floor plan and cross-section of the basilica published in 1733, seems to show the nave arcade piers evenly spaced. Rocchi et al. appear to do the same in their larger and more detailed floor plans of 1988.⁸² Gustavo Uzielli's dubious claim that in 1896 he recorded several measurements between the nave piers and found that the average corresponded exactly to the nave

bay widths specified in a document of 1357 (discussed below) demonstrates that he, too, assumed that all the bays were of equal width.⁸³ My measurements reveal a more complex situation.⁸⁴ The widths of the nave arcade bays vary by as much as 1.2 br (70.5 cm) from one to the next, and those width irregularities are not randomly distributed, but occur in approximately corresponding pairs down the length of the nave.⁸⁵ The westernmost bay in each nave arcade (adjacent to the interior façade) each measures nearly exactly 29 br plinth to plinth. The next bay to the east in each arcade measures approximately $29 \frac{1}{10}$ br; the next, between $28 \frac{1}{2}$ br and $28 \frac{1}{3}$ br; and the last, about 28 br (Figure 5-18). These variations would be too large to permit proportional analysis of the individual nave arcade bays were it not for a surviving document that specifies the originally-intended bay dimensions.

Records of the cathedral *Opera* indicate that the design of the nave arcades received careful review by an expert committee for nearly two years before being finalized. On 26 June 1355, the committee decided that a model of the basilica then being made by Talenti was too expensive, and thus should be built “[...] only as far as two columns and the vaults of the arches [...]”⁸⁶ Evidently the committee expected all the nave bays to be identical, and believed that a model of just one nave bay would suffice. A few weeks later, another committee examined “[...] the models of the columns and the measurements.”⁸⁷ On 17 June 1357, the floor plan dimensions were formally established as follows:

And that it is intended that the space from middle of column to middle of column be $33 \frac{3}{8} \frac{1}{1}$ *braccia* for the width [of the nave]. And for the length, 34 br. From which [are to] follow three vaults [i.e., vaulted bays], one after the other, from middle of column to middle of column, in width thirty-three and three-eighths and a half *braccia*; [and] in length, 34 *braccia*, from middle of column to middle of column.⁸⁸

Let us first examine the 1357 east-west bay width specification (called “length” in the preceding quotation, but nowhere else in this study). Since according to my survey most of the nave pier footprints measure nearly exactly 5 br (291.8 cm) wide, the specified bay width of 34 br (1984.24 cm) on center equals 29 br (1692.44 cm) plinth to plinth (Figures 5-18 and 5-19).⁸⁹ As noted above, this measurement was in fact executed only in the westernmost bay of the nave (Figure 5-18).⁹⁰ Since the nave was built from west to east, this combination of metrical and documentary evidence suggests that only the first bay was built precisely to specification. Less than a decade later,

the second bay was stretched slightly and the third bay was compressed, for a total loss of about $\frac{1}{2}$ br from the combined widths of all three originally-specified nave bays. A fourth bay was added to the design of the basilica on 13 July 1366, and committed to stone in 1377. According to my measurements, this bay was reduced by about a full *braccio* from the originally-specified bay width (Figure 5-18).⁹¹

The reasons for the increase and subsequent decrease in the widths of the second through fourth bays of the nave (counting from west to east), after the first bay correctly established the width specified in 1357, are unknown. Perhaps, following Arnolfo di Cambio's late thirteenth-century beginnings, the fourteenth-century construction effort that proceeded from the west had to accommodate some preexisting work laid by Arnolfo.⁹² Alternatively, the variations perhaps represent the common medieval practice of incorporating architectural refinements into large buildings for the purpose of adding visual richness.⁹³ Whatever the reasons for the dimensional variations in the nave bay widths, the preceding analysis indicates that the first (westernmost) bay contains the width that Talenti originally intended for all the bays. Let us examine that width in more detail.

The committee charged by the *Opera* with approving the dimensions of the nave arcade bays may have found on center measurements to be expedient when describing key width dimensions in a document, but Talenti appears to have determined the proportions of his nave arcade bays by measuring plinth to plinth. Had all the nave arcade bays been built with a plinth to plinth distance of 29 br as Talenti apparently intended (and not merely the westernmost bay in each arcade), then because of the 5 br pier plinths, the distance between the *farther edges* of the two plinths in each bay would be 39 br (Figure 5-19).

A square-and-a-half inscribed horizontally between two plinths spaced as such has a height of $19\frac{1}{3}$ br. A two-square rectangle drawn horizontally to touch the *farther edges* of those plinths has a height of $19\frac{1}{2}$ br. These two geometrical figures *nearly* overlap along their top edges, with a discrepancy of $\frac{1}{6}$ br (9.75 cm), or, 0.86% (Figure 5-19). Apparently this near-overlap was close enough for Talenti and the *Opera*'s conception of geometrical correspondence. The pier shafts, which vary in height (measured to the bottoms of the astragals) by just a few centimeters from one to the next, have a mean height of 1133.69 cm, or, just 0.53 cm taller than $19\frac{5}{12}$ br.⁹⁴ This height falls exactly midway between $19\frac{1}{3}$ br and $19\frac{1}{2}$ br. Thus, by splitting the difference between the heights

of the two rectangles in question Talenti gave equal importance to both, and thereby effectively ignored the geometrical height discrepancy. Talenti appears to have been equally willing to ignore numerical discrepancies for the sake of finding proportional order.

The width and height dimensions of both the aforementioned square-and-a-half and double square, arranged in size order, are:

$$19\frac{1}{3}, 19\frac{1}{2}, 29, 39$$

In the San Lorenzo nave arcade bay set of proportions, I have shown that the fractional endings of $\frac{2}{3}$ attached to several key dimensions serve as graphic flags indicating that those dimensions must be grouped together before the numerical significance of the set of proportions can be read. Then, to reveal that significance, the fractions must be ignored (Figure 4-12).⁹⁵ In the set of proportions designed by sets of proportions for the Santa Maria del Fiore nave arcade bays, by contrast, it seems that the fractions must be ignored right away. Removing them, and the resultant duplicate whole number, produces the progression:

$$19, 29, 39$$

Thus we have a number progression that increases by increments of 10, always leaving 9 as the last digit. Nine (9), as the square of 3, symbolizes the Trinity, and is thus consistent with the Trinitarian symbolism implied by the original 3 nave bays and 3 tribunes in the basilica floor plan before the fourth nave bay was added. Perhaps also significant to Talenti was the correspondence between the sum of the three numbers in the above progression and the sum of the original three bay widths, measured plinth to plinth; thus: $19 + 29 + 39 = 87$, and $29 + 29 + 29 = 87$.

We have now examined the width-to-height proportions of only the lower order in the Santa Maria del Fiore nave arcades, measured to the tops of the pier shafts. There are two levels of column-like nave piers, however, one stacked atop the other (Figures 5-17 and 5-19). The heights from the floor to the tops of the upper pier shafts (again marked by the bottoms of the astragals) vary by just a few centimeters from one pier to the next, and closely converge around the dimension 41 br.⁹⁶

Considered together as a pair, the height of 41 br and the plinth to plinth distance of 29 br produce an extremely accurate approximation of the ratio $1:\sqrt{2}$.⁹⁷ This pair thus effectively describes a root-2

rectangle, inscribed between adjacent pier plinths, that rises to the tops of the upper pier shafts within discrepancies of no more than 7 cm, or just 0.3% (Figures 5-20 and 5-21).⁹⁸

Possible San Lorenzo Seed Numbers

The appearance of the width-to-height ratio 29:41 in the Santa Maria del Fiore nave arcade bays is striking because the same ratio appears in the San Lorenzo nave arcade bays, in the form $9\frac{2}{3} : 13\frac{2}{3}$. The latter can be converted to 29:41, and vice versa, through simple fractional arithmetic that was well within the capabilities of educated Florentines by the late fourteenth century (Figures 4-12, 5-17 and 5-20).⁹⁹ The ratio 29:41, in turn, can be derived from a simple formula that generates an infinite progression of whole number approximations of the ratio $1:\sqrt{2}$. This formula is described in a treatise on arithmetic written by Theon of Smyrna in the first century, A.D., which could possibly have been available in Florentine learned circles by the late fourteenth century.¹⁰⁰ Thus, while Dolfini (or Brunelleschi, if one prefers) could possibly have learned of the ratio 29:41 through an intellectual environment that had absorbed the lessons of Theon's treatise, another possibility, which does not preclude the first, is that he learned it directly from the Basilica of Santa Maria del Fiore.

The similarities between the nave arcade bay sets of proportions found in the basilicas of Santa Maria del Fiore and San Lorenzo go beyond the use of the ratio 29:41 and its alternate form, $9\frac{2}{3} : 13\frac{2}{3}$. Also similar is the way in which this ratio is used. In both sets of proportions this ratio describes the dimensions, in *braccia*, of a root-2 rectangle that is part of a framework of three overlapping (or in the case of Santa Maria del Fiore, nearly overlapping) geometrical figures, all of which are based on the square and its diagonal. In both sets of proportions that framework touches the nearer and farther edges of the two column or pier plinths in each bay, and (exactly or nearly) the tops of the column shafts measured to the bottoms of the astragals (Figures 4-12, 5-19 and 5-20).¹⁰¹ In both, furthermore, the numbers that describe the widths and heights of all of these overlapping geometrical figures do double duty as both dimensional specifications and bearers of non-quantitative meaning. Regarding the latter, both employ fractions in supportive roles that require that the fractions be ignored at appropriate moments, such that the whole numbers to which they are attached can be read as components of number progressions that denote abstract meanings ultimately related to the medieval concept of *ordine* (lit. "order").¹⁰²

In light of these similarities, we may reasonably hypothesize that Dolfini began his design of the San Lorenzo nave arcade bay set of proportions by reducing the key dimensions of the Santa

Maria del Fiore set of proportions by two-thirds. In order to explore this hypothesis, let us first review the key dimensions of the San Lorenzo nave arcade bay set of proportions, which are (refer to Figure 4-12):

$$1 \frac{2}{3} \text{ br, } (5 \frac{2}{3} \text{ br,}) 9 \frac{2}{3} \text{ br, } 13 \frac{2}{3} \text{ br, and } 17 \frac{2}{3} \text{ br.}$$

Other important San Lorenzo nave arcade dimensions include:

$$1 \frac{1}{2} \text{ br, } 2 \text{ br, and } 2 \frac{1}{3} \text{ br.}$$

Returning now to Santa Maria del Fiore and dividing all the key dimensions by 3 using simple fractional arithmetic (as noted above) produces the following dimensions (refer to Figures 5-19 and 5-20): the plinth width reduces from 5 br to $1 \frac{2}{3}$ br; the plinth to plinth distance, from 29 br to $9 \frac{2}{3}$ br; the distance between the farther edges of the pier plinths, from 39 br to 13 br; the lower pier shaft height, from $19 \frac{5}{12}$ br to $6 \frac{17}{36}$ br; and the upper pier shaft height, from 41 br to $13 \frac{2}{3}$ br. Thus, the newly scaled-down dimensions from the Santa Maria del Fiore nave arcade bays, arranged in size order, are:

$$1 \frac{2}{3}, 6 \frac{17}{36}, 9 \frac{2}{3}, 13, 13 \frac{2}{3}$$

Three of these numbers, $1 \frac{2}{3}$, $9 \frac{2}{3}$, and $13 \frac{2}{3}$, which no longer need be associated with their original locations in the Santa Maria del Fiore nave arcade bay set of proportions, perhaps served as numerical seeds of the San Lorenzo nave arcade bay set of proportions. From them Dolfini perhaps began to visualize the major elements of that future set of proportions, including the accurate numerical approximation of the proportions of the root-2 rectangle, the use of those numbers in a Boethian number progression, and the use of common repeated fractions to call out those numbers as a group (Figures 4-12). Another important dimension in the Santa Maria del Fiore nave that might have helped Dolfini along in this direction is the height from the floor to the top of the upper gallery (*ballatoio*) railing. Although it does not appear to be incorporated into the Santa Maria del Fiore set

of proportions, this height (A in Figure 5-19) varies from about 51 br to $51\frac{2}{3}$ br (Figure 5-21).

Dividing this varying height by 3 produces dimensions that range from about 17 br to $17\frac{1}{5}$ br. This reduction thus adds the number 17 (albeit without the fraction $\frac{2}{3}$) to the array of seed numbers that Dolfini perhaps derived from the Santa Maria del Fiore nave arcades for eventual incorporation into the San Lorenzo nave arcade bay set of proportions (Figure 4-12). Let us recall, furthermore, that since Brunelleschi appears to have based the Santo Spirito arcade bay set of proportions on the nave arcade bay set of proportions of San Lorenzo, any seed numbers that may have influenced Dolfini in his development of the San Lorenzo set of proportions must necessarily also be considered seed numbers for the Santo Spirito set of proportions.

The Santa Maria del Fiore nave arcades could have provided yet one more seed number for Dolfini, this one hidden underground. The aforementioned document of 19 June 1357 specifies “that the foundation of each column from the space [of the nave] down is to be made 7 br per side, square, down to good gravel in water.”¹⁰³ Note that 7 br divided by 3 equals $2\frac{1}{3}$ br, the likely intended height of both the San Lorenzo and Santo Spirito entablature blocks (Figures 2-50 and 4-12).¹⁰⁴ I have previously noted that this dimension, in combination with the San Lorenzo and Santo Spirito capital height of $1\frac{2}{3}$ br, produces the ratio $1\frac{2}{3} : 2\frac{1}{3}$ (Figure 4-12), which is equivalent to 5:7; a ratio that constitutes another whole number approximation of the ratio $1:\sqrt{2}$ that can be derived from Theon of Smyrna’s formula.¹⁰⁵ In the Basilica of Santa Maria del Fiore the same ratio is generated from the 7 br square nave pier foundation noted in the document of 1357, in combination with the essentially 5 br square plinths that they support (Figure 5-18). The use of the ratio $1:\sqrt{2}$, or its close approximation, to determine the thicknesses of foundations relative to the columns or walls that they support may have been common practice during the medieval and Renaissance periods. Sebastiano Serlio, for example, citing Vitruvius, notes that relative thicknesses of temple walls and their foundations should be the same as the relative widths of two consecutive squares in a rotation of squares series, or, $1:\sqrt{2}$.¹⁰⁶

Imprecision in Sets of Proportions

However striking the above-noted similarities between the San Lorenzo and Santa Maria del Fiore nave arcade bay sets of proportions may be, one significant difference between them remains: while the San Lorenzo set of proportions embodies remarkable geometrical and mathematical

precision, the Santa Maria del Fiore set of proportions embodies remarkable *imprecision*.¹⁰⁷ Most notably, the overlapping square-and-a-half and double square, based on the plinth to plinth dimensions of 29 br and 39 br, respectively, fail to perfectly overlap along their top edges (Figure 5-19). This imprecision cannot be attributed to construction error, as I have argued is the case with a comparably-sized imprecision in the San Lorenzo nave arcade proportions, because here the problem is geometrical—these particular rectangles, with the base dimensions of 29 br and 39 br, simply do not fit together perfectly.¹⁰⁸ Furthermore, in the Santa Maria del Fiore set of proportions as described above, in order to access the whole-number progression 19, 29, 39, fractions must be removed from occurrences of the first number (in the forms of $19\frac{1}{3}$ br and $19\frac{1}{2}$ br) but not the others. This inconsistency contrasts markedly with the San Lorenzo set of proportions, in which all the components of a number progression that Dolfini apparently wanted to call attention to bear the common fractional ending $\frac{2}{3}$.

There would seem to be but two possible explanations for the presence of these instances of imprecision in the Santa Maria del Fiore set of proportions: either my hypothesis is incorrect, and the set of proportions described above is in fact not intentional but merely a series of imperfect geometrical and numerical coincidences; or Talenti had a greater tolerance for proportional imprecision than Dolfini did by the time Dolfini designed the San Lorenzo nave arcade bay set of proportions. The first possibility cannot be discounted. My hypothesis accounts for the broad outlines of the Santa Maria del Fiore nave arcade bay proportions, tied to many of the same points of measurement as is the San Lorenzo nave arcade bay set of proportions, but it does not account for several important dimensions such as the heights of the capitals, entablature block strips, and both the top and bottom of the *ballatoio*. There may yet be additional parts of the set of proportions that I have described above, or another nave arcade bay set of proportions altogether, awaiting discovery that will provide a more complete explanation for all the key dimensions of the nave arcades; though if there is one I have not found any evidence of it.

Nevertheless, in light of these uncertainties, I present the results of the preceding analysis as a working hypothesis—a designation that makes it no less productive a vehicle for exploring the principles of medieval architectural proportion than a more secure hypothesis would be. If we assume, for the remainder of this study, that the Santa Maria del Fiore nave arcade bay set of proportions described above was indeed intentionally designed by Talenti, then we need to explain how an architect capable of addressing all the technical demands inherent in the design of a major cathedral could have tolerated the geometrical and numerical imprecision that this set of proportions

embodies. To do so, we need to explore the history of medieval arithmetic as a reflection of medieval attitudes about quantification.

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¹ “[...] the sacristy went forward before every other thing and advanced to a state that aroused the marvel of everyone in the city, and of the visitors who chanced to see it, because of its new and beautiful style. The many people constantly gathering there caused great annoyance to those working there.” Antonio Manetti, *Vita di Filippo Brunelleschi*, Giuliano Tanturli, ed., Milan 1976, p. 109.

² Antonio di Tuccio Manetti, who who died in 1497 and probably composed the *Vita di Filippo Brunelleschi* in the 1480s, did not likely witness the completion of the Old Sacristy. Nevertheless, at the time of his writing it was an event from the recent history of the city, and he could conceivably have spoken with others who did witness it. On the date of the *Vita* see Antonio di Tuccio Manetti, *The Life of Brunelleschi*, Howard Saalman, ed., University Park and London 1970, “Introduction,” p. 10.

³ Matthew A. Cohen, “How Much Brunelleschi? A Late Medieval Proportional System in the Basilica of San Lorenzo in Florence,” *Journal of the Society of Architectural Historians*, LXVII, 1, 2008, p. 18 and note 2; and Rudolf Wittkower, “Brunelleschi and ‘Proportion in Perspective’”, *Journal of the Warburg and Courtauld Institutes*, XVI, 3-4, 1953, pp. 275-291.

⁴ Cohen, Ivi, pp. 41-43.

⁵ Ivi, pp. 18-57.

⁶ Sets of proportions consist of geometrical, numerical and arithmetical relationships that can be comprehended only mentally, not visually. Modern observers who attribute architectural beauty and value to set of proportions (whether rigorously documented or imagined) perpetuate a mystical belief system that traces back through the Romantic period to the medieval and Renaissance periods.

⁷ Giorgio Vasari, *Le Vite de' più eccellenti architetti, pittori, et scultori italiani da Cimabue insino a' tempi nostril: Nell'edizione per I tipi di Lorenzo Torrentino, Firenze 1550*, ed. by Luciano Bellosi and Aldo Rossi, Torino 1986, p. 283: “... solo l'intento suo era l'architettura, che già era spenta, dico gli ordini antichi buoni e non la todesca e Barbara, quale molto si usava nel sup tempo”. Manetti, *Vita*, cit, [cfr. note 1], pp. 48: “[...] si rinnovò questo modo de' muramenti che si dicono alla romana ed alla antica, a che molto vanamente si va oggi tanto dietro; e chi di nuovo l'arecò a luce; ché prima

erano tutti tedeschi [...]”, 55, 64-70, 76. Other early promoters of this view include Filarete and Giovanni Rucellai. Howard Burns, “Quattrocento Architecture and the Antique: Some Problems”, in R.R. Bolgar (ed.), *Classical Influences on European Culture A.D. 500-1500: Proceedings of an International Conference Held at King's College, Cambridge, April 1969*, Cambridge 1971, p. 277 note 3. Francesco Paolo Fiore, “Introduzione”, *Storia dell'architettura italiana: Il quattrocento*, Francesco Paolo Fiore (ed.), Milan 2007, II ed., p. 9. Ernst H. Gombrich, “From Revival of Letters to the Reform of the Arts: Niccolò Niccoli and Filippo Brunelleschi”, Douglas Fraser, Howard Hibbard, Milton J. Lewine (editors), *Essays in the History of Art Presented to Rudolf Wittkower*, London 1967, p. 79. For two early survey text references to Brunelleschi as the reviver of ancient Roman architecture, see Banister Fletcher, *A History of Architecture on the Comparative Method*, XVI ed., New York 1958, pp. 624, 629, and earlier editions; and William Henry Goodyear, *Renaissance and Modern Art*, London 1900, p. 73. See also John Onians, *Bearers of Meaning: The Classical Orders in Antiquity, the Middle Ages, and the Renaissance*, Princeton 1988, p. 130; Howard Saalman, “Filippo Brunelleschi: Capital Studies”, *The Art Bulletin* XL, 2, 1958, pp. 114-115; and Marvin Trachtenberg, “Gothic/Italian ‘Gothic’: Toward a Redefinition,” *Journal of the Society of Architectural Historians*, L, 1, 1991, pp. 22-23.

⁸ “[...] their musical proportions [...]” Manetti, *Vita*, cit. [cfr. note 1], p. 66. Whether or not it is accurate, this comment may represent an attempt on Manetti’s part to associate Brunelleschi with the avant-garde architectural theories of Alberti, whose *De re aedificatoria* was published around the time Manetti composed the *Vita*, and which contains a detailed discussion of musical proportions. Leon Battista Alberti, *De re aedificatoria*, Florence 1486, IX, 10.

⁹ Carl von Stegmann and Heinrich von Geymüller, *Die Architektur der Renaissance in Toskana*, Munich 1885, I, p. 18. For the term “metrical coherence”, and variations thereof in relation to the work of Brunelleschi, see Wittkower, “Brunelleschi and ‘Proportion in Perspective’”, cit. [cfr. note 3], pp. 132-133, 275-291.

¹⁰ Vasari does not only associate Brunelleschi’s style with ancient Roman architecture [cfr. note 7], but also with a prominent example of the Tuscan Romanesque style in Florence, the Basilica of Ss. Apostoli: “In Fiorenza poi migliorando alquanto l’architettura, la chiesa di Sant’Apostolo, che fu edificata da Carlo Magno, fu, ancor che piccolo, di bellissima maniera.... In somma, l’architettura di questa chiesa e tale, che Pippo di ser Brunellesco non si sdegnò di servirsene per modello nel fare la chiesa di Santo Spirito et quella di San Lorenzo nella medesima città.” Giorgio Vasari, *Le vite de’ piu eccellenti pittori scultori e architettori*, Karl Frey (ed.), Munich 1911, I, p. 195. Building upon this comment by Vasari, Dehio notes that the correspondences between the Basilicas of Ss. Apostoli,

San Lorenzo, and Santo Spirito are precise enough to preclude any inspiration from Rome on the part of Brunelleschi. Georg Dehio, "Romanische Renaissance", *Jahrbuch der königlich preussischen Kunstsammlungen*, 7, 1886, p. 129. Saalman believes that Dehio's Brunelleschi/Tuscan Protorenaissance connection is "somewhat overemphasized", since Saalman observes notable differences between the capitals of Brunelleschi and their Tuscan Romanesque predecessors. Saalman, "Filippo Brunelleschi: Capital Studies Capital Studies", cit. [cfr. note 7], p. 115.

¹¹ "...in Rome, from the classical exemplars, but rather in Florence and elsewhere from medieval works of Romanesque character...". Paolo Fontana, "Il Brunelleschi", *Atti del X congresso internazionale di storia dell'arte in Roma*, Rome 1922, p. 177. Cf. Id., "Il Brunelleschi e l'architettura classica", *Archivio storico dell'arte*, VI, 1893, pp. 256-267.

¹² On Hoffman and Horster see discussion and references in Trachtenberg, "Brunelleschi, 'Giotto' and Rome", cit. [cfr. note 12], p. 677. Heinrich Klotz, *Filippo Brunelleschi: The Early Works and the Medieval Tradition*, London 1990. Uta Schedler, *Sythese con Antike und Mittelalter in der Renaissance*, Petersberg 2004, pp. 11-15. Burns, "Quattrocento Architecture and the Antique", cit. [cfr. note 7], pp. 271-275, 281. Peter Murray, *Architecture of the Italian Renaissance*, New York 1963, pp. 10-15, 33-34. Arnaldo Bruschi, "Religious Architecture in Renaissance Italy from Brunelleschi to Michelangelo," in Henry A. Millon and Vittorio Magnago Lampugnani (eds.), *The Renaissance from Brunelleschi to Michelangelo: The Representation of Architecture*, New York 1994, p. 125. Marvin Trachtenberg, "Brunelleschi, 'Giotto' and Rome", cit. [cfr. note 12], pp. 677-680. Isabelle Hyman, "The Venice Connection: Questions About Brunelleschi and the East", Sergio Bertelli, Nicolai Rubinstein, and Craig Hugh Smyth (eds.), *Florence and Venice: Comparisons and Relations*, Florence 1978, I, p. 194 and references therein. *Filippo Brunelleschi: La sua opera e il suo tempo*, I-II, Florence 1980, contributions by Arnaldo Bruschi et. al., Cesare Calano, and Volker Hoffman, II, pp. 389-458. John Onians, "Brunelleschi: Humanist or Nationalist?", *Art History*, V, 3, 1982, pp. 259-271. Onians, *Bearers of Meaning*, cit. [cfr. note 7], pp. 130-146. Arnaldo Bruschi, *Filippo Brunelleschi*, Milan 2006, pp. 53-175.

¹³ Burns, "Quattrocento Architecture and the Antique...", cit. [cfr. note 7], pp. 277-283. Klotz, *Filippo Brunelleschi: The Early Works...*, cit. [cfr. note 12], pp. 133-139.

¹⁴ Hyman, "The Venice Connection...", cit. [cfr. note 12], pp. 193-208, and Fabriczy as cited therein, note 1.

¹⁵ Marvin Trachtenberg, "On Brunelleschi's Old Sacristy as Model for Early Renaissance Church Architecture", in Jean Guillaume (ed.), *L'Église dans l'architecture de la Renaissance*, Paris 1995, pp. 16-22.

¹⁶ Piero Sanpaolesi, “La Cupola di Santa Maria del Fiore ed il Mausoleo di Soltanieh”, *Mitteilungen des Kunsthistorischen Institutes in Florenz* XVI, 3, 1972, pp. 221-260.

¹⁷ Hyman, “The Venice Connection...”, cit. [cfr. note 12], p. 206. Irving Lavin, “Donatello's Bronze Pulpits in San Lorenzo and the Early Christian Revival”, in *Past-Present: Essays on Historicism in Art from Donatello to Picasso*, Berkeley 1993, pp. 1-27. According to Trachtenberg, of interest to Brunelleschi were not only the Early Christian basilicas of Rome and the later medieval recreations thereof, but also antique buildings later consecrated as churches, notably including the Pantheon, rededicated as Santa Maria Rotunda. Marvin Trachtenberg, “On Brunelleschi's Choice: Speculations on Medieval Rome and the Origins of Renaissance Architecture”, in Cecil L. Striker (ed.), *Architectural Studies in Memory of Richard Krautheimer*, Mainz 1996, pp. 169-173.

¹⁸ Onians, *Bearers of Meaning*, cit. [cfr. note 7], p. 130. Trachtenberg, “Brunelleschi, ‘Giotto’ and Rome”, cit. [cfr. note 12], p. 675, and references therein.

¹⁹ Richard Cocke, “Masaccio and the Spinario, Piero and the Pothos: Observations on the Reception of the Antique in Renaissance Painting”, *Zeitschrift für Kunstgeschichte*, XLIII, 1, 1980, pp. 21-32.

²⁰ Leonardo Benevolo, Stefano Chieffi, and Giulio Mezzetti, “Indagine sul S. Spirito di Brunelleschi”, *Quaderni dell'istituto di storia dell'architettura*, XV, 85-90, 1968, pp. 34-49. Francesco Quinterio, “Il cantiere della chiesa: il vestibolo e la sagrestia”, in Cristina Acidini Luchinat (ed.), *La chiesa e il convent di Santo Spirito a Firenze*, Florence 1996, pp. 91-99.

²¹ Vasari, *Le vite*, cit. [cfr. note 7], p. 285.

²² Manetti, *Vita*, cit. [cfr. note 1], p. 77-80.

²³ Vasari, *Le vite*, cit. [cfr. note 7], p. 285.

²⁴ Eugenio Battisti, *Filippo Brunelleschi: The Complete Work*, New York 1981, p. 334.

²⁵ Trachtenberg, “Brunelleschi, ‘Giotto’ and Rome”, cit. [cfr. note 12], p. 681.

²⁶ Burns furthermore notes: “[...] it is much more likely than not that Brunelleschi went to Rome and studied its monuments on one or more occasions”. Burns, “Quattrocento Architecture...”, cit. [cfr. note 7], pp. 277, 283, 286.

²⁷ In addition to his early travels Brunelleschi, according to Manetti, continued to travel later in his life as well, at the frequent invitation of diverse municipalities. Manetti, *Vita*, cit. [cfr. note 1], p. 99.

²⁸ Marvin Trachtenberg, “Brunelleschi, ‘Giotto’ and Rome”, cit. [cfr. note 12], p. 675.

²⁹ Frank D. Prager and Gustina Scaglia, *Brunelleschi: Studies of his technology and Inventions*, Cambridge, Massachusetts and London 1970, pp. 2-18.

³⁰ This quotation is in reference to a convocation conceived, according to Manetti, by Brunelleschi in 1419 with regard to construction of the cupola. Manetti, *Vita*, cit. [cfr. note 1], p. 79.

³¹ James S. Ackerman, “‘Ars Sine Scientia Nihil Est’: Gothic Theory of Architecture at the Cathedral of Milan”, *Art Bulletin* XXXI, 2, June 1949, 84-111. Luciano Bellosi, et al, *La Basilica di San Petronio in Bologna*, Milan 1983. Mario Fanti and Deanna Lenzi (eds.), *Una basilica per una città: sei secoli in San Petronio*, Bologna 1994. Richard J. Tuttle, “The Basilica of S. Petronio in Bologna”, in Millon and Magnago Lampugnani, *The Renaissance...*, cit. [cfr. note 12], pp. 522-527, cf. 429-430. Richard J. Tuttle, “Bologna”, in Francesco Paolo Fiore, *Storia dell’architettura italiana: il quattrocento*, II ed., Milan 2007, pp. 256-259.

³² In 1404 Brunelleschi served on a board of nineteen advisers to the *Opera* of the Cathedral of Florence that voted to require partial reconstruction of a buttress newly completed by the then *capomaestro*, Giovanni d’Ambrogio. Prager and Scaglia, *Brunelleschi...*, cit. [cfr. note 29], pp. 15-16. Vasari notes that Brunelleschi advised the master masons of the Cathedral of Milan during one of his trips to that city. Vasari, *Le Vite*, cit. [cfr. note 7], p. 302. According to Battisti, Brunelleschi was mentioned in an undated, now destroyed fifteenth-century list of architects active at the Cathedral of Milan. Gaetano Franchetti, *Storia e descrizione del duomo di Milano*, Milan 1908, p. 21 as cited in Battisti, *Filippo Brunelleschi...*, cit. [cfr. note 24], p. 374 n. 8. The reference does not appear in the 1821 edition of Franchetti’s *Storia*, however, and I have been unable to locate a copy of the above-cited 1908 edition.

³³ Fabio Benedettucci (ed.), *Il libro di Antonio Billi*, Rome 1991, p. 34. Cohen, “How Much Brunelleschi?...”, cit. [cfr. note 3], p. 53 note 58.

³⁴ “[...] 8 Lombards [...]” Manetti, *Vita*, cit. [cfr. note 1], pp. 96-97.

³⁵ Note that Giuliano da Sangallo often made his own editorial modifications to known buildings in his sketches. While the deep nave chapels he shows in the sketch in question are consistent with other historical evidence, there is no reason to believe that the portico, numerous domical vaults, or second sacristy that he also depicts conform to Brunelleschi’s intentions.

³⁶ Cohen, “How Much Brunelleschi?...”, cit. [cfr. note 2], pp. 37-44.

³⁷ “[...] unwilling, because it seemed to him a miserable thing [...]” Manetti, *Vita*, cit. [cfr. note 1], pp. 107-108. Caroline Elam has noted to me the problematic nature of this passage, since the construction of the basilica during Giovanni de’ Medici’s lifetime was a corporate enterprise, not an act of individual patronage. In this passage Manetti may be confusing the role of Giovanni with that of his son Cosimo de’ Medici, who after 1442 accepted sole responsibility for construction of most of the basilica. Even if Manetti has confused some of the facts, however, the account may correctly indicate that Giovanni had substantial influence over important design decisions, and that private chapel patrons were difficult to find. The other details of the account, furthermore, would seem to be

too specific to dismiss entirely. Though perhaps not factually flawless, as a first hand fifteenth century account Manetti's *Vita* must be given careful consideration.

³⁸ “[...] the present body of the church from the transept downward [i.e., the nave], does not conform to the aforesaid transept [...]”, Manetti, *Vita*, cit. [cfr. note 1], p. 111.

³⁹ Saalman, *Filippo Brunelleschi: The Buildings*, University Park, Pennsylvania 1993, p. 107.

Richard A. Goldthwaite, *The Building of Renaissance Florence: An Economic and Social History*, Baltimore 1980, pp. 98-102. Antonio Ivan Pini, “Tra orgoglio civico e ‘status symbol’: corporazioni d’arte e famiglie aristocratiche in San Petronio nel XIV e XV secolo”, in Fanti and Lenzi, *Una basilica per una città...*, cit. [cfr. note 31], pp. 87-100.

⁴⁰ Saalman, conversely, believes that Brunelleschi took the Santa Trinita floor plan as his model for San Lorenzo. Saalman, *Ivi*, pp. 206-207. Saalman’s detailed proposed reconstruction for this Santa Trinita-inspired scheme is problematic, however, for it includes freestanding, square, fluted, minor order columns—a device that occurs nowhere in the Brunelleschi oeuvre and would have significantly complicated Brunelleschi’s otherwise lucid architectural language. For a tentative chronology of the fourteenth-century rebuilding of the Basilica of Santa Trinita see Howard Saalman, *The Church of Santa Trinita in Florence*, CAA Monograph XII, 4, 1966, pp. 37-38. Fontana, “Il Brunelleschi”, cit. [cfr. note 11], p. 173. Readers should not interpret my assessments that this basilica lacks “geometrical clarity” and provides an “unremarkable interior experience” as in any way related to each other. Only according to the Wittkower Paradigm, which I do not agree with, could geometrical clarity be believed to contribute to a remarkable interior experience. Rather, I simply mean that a fifteenth-century architect, such as Dolfini or Brunelleschi, who looked at a floor plan drawing of this basilica and toured the interior is not, in my opinion, likely to have been impressed enough to have chosen this basilica as a model for a new one. I am using my aesthetic assessment here not as a form of historical evidence, but merely to suggest one way in which a fifteenth-century Florentine architect might have evaluated nearby precedents in search of appropriate models for a new work. My main argument is not based on my aesthetic opinions, but on the extensive evidence presented below that points to northern influences on the San Lorenzo design, rather than influences from the basilica of Santa Trinita. See Chapter 1 for a description of the Wittkower Paradigm.

⁴¹ “[...] with brick piers [...]”. Manetti, *Vita*, cit. [cfr. note 1], p. 106.

⁴² The molded brick capitals of the former nave columns in the partially-preserved Romanesque Basilica of San Pier Scheraggio (today part of the Uffizi) is the only significant, surviving medieval example of the visible use of this building material in Florentine ecclesiastical architecture.

⁴³ Giovanni Lorenzoni, “L’architettura”, in *La Basilica di San Petronio in Bologna*, Milan 1983, pp. 53-124.

⁴⁴ Whether Dolfini intended compound piers to support a vaulted nave, or nave columns to support a flat wooden ceiling, is unknown. See note 52, below.

⁴⁵ Ackerman, “‘Ars Sine Scientia Nihil Est’...”, cit. [cfr. note 31], p. 88. For a high-quality color reproduction of this sketch see Christoph Luitpold Frommel, “Reflections on the Early Architectural Drawings”, in Millon and Magnago Lampugnani (eds.), *The Renaissance from Brunelleschi to Michelangelo...*, cit. [cfr. note 12], p. 103 Fig. 5.

⁴⁶ That Pavia remained a destination of architectural interest more than a century after the founding of the cathedral in nearby Milan is suggested by Giuliano da Sangallo’s visit to Pavia in 1492. His sketch of the “Tower of Boethius”, or according to Giuliano’s own label, “La Tore di Pavia” (the tower in which Severinus Boethius was imprisoned and eventually executed), is now a valuable record of the appearance of that ancient monument, which collapsed in 1584. Vittorio Prina (ed.), *Vedute di Pavia dal ‘500 al ‘700*, Pavia 1992, pp. 205, 218-219. Arioldo moved the seat of the Longobard kingdom to Pavia in the early seventh century. Gian Piero Bognetti, “Colombano a Milano—la politica universale a le reazione barbarica”, *Storia di Milano*, II, Milan 1954, p. 161. Pavia was destroyed by the Hungarians in 924, and burned in an uprising of 1004. “Pavia,” *Enciclopedia italiana di scienze, lettere ed arti* 26, Rome: Istituto della Enciclopedia Italiano, 1935, p. 542. The kingdom did not reach the peak of its prosperity until the eleventh and twelfth centuries, and most Romanesque monuments in Pavia today date to the twelfth century.

⁴⁷ Giovanni Mariacher, “Bernardo e Niccolò da Venezia”, *Rivista d’arte*, Anno XXIV (Serie II, Anno XIV), 1-2, 1942, pp. 12-25. Angiola Maria Romanini, “L’architettura viscontea e Bernardo da Venezia”, “La Certosa di Pavia dalla fondazione sino alla metà del xv secolo”, and “La chiesa di S. Maria del Carmine a Milano nella prima metà del quattrocento”, *Storia di Milano*, VI, 1955, pp. 611-648. Id., *L’architettura gotica in Lombardia*, I, Milan 1964, pp. 415-436.

⁴⁸ On the Viscontean works listed here see articles by Angiola Maria Romanini in *Storia di Milano*, Ibid. Romanini, *L’architettura gotica in Lombardia*, Ivi, I, pp. 415-429. See additional bibliographical references in James S. Ackerman, Postscript to “The Certosa of Pavia and the Renaissance in Milan”, *Distance Points*, Cambridge, Massachusetts 1991, pp. 300-302. For a summary of the dates of Visconti rule, see “Tavola Genealogico della Famiglia Visconti – III”, *Storia di Milano*, VI, 1955. For a review of documentary evidence pertaining to the beginning date of construction of the Carmine, see Faustino Gianani, *Il Carmine di Pavia: storia e guida del grande monumento*, Pavia 1962, p. 13. Romanini, “L’architettura viscontea e Bernardo da Venezia”, Ivi, pp.

613-615; Romanini, *L'architettura gotica in Lombardia*, Ivi, I, pp. 419, and 475 note 13. Hermann Oertel, *Die baugeschichte der kirche "S. Maria del Carmine" in Pavia*, Pavia 1936, pp. 17-35.

⁴⁹ For the comparison with the Cathedral of Florence, see Lorenzoni, "L'architettura", cit. [cfr. note 42], p. 60.

⁵⁰ Ackerman, "'Ars Sine Scientia Nihil Est'...", cit. [cfr. note 31], pp. 87-111.

⁵¹ Gianani provides simple single-line diagrams comparing the nave bay systems of the basilicas of San Petronio and Santa Maria del Carmine of Pavia. Gianani, *Il Carmine di Pavia...*, cit. [cfr. note 48], p. 20. Lorenzoni notes that San Petronio has lateral chapels similar to those of the Carmine of Pavia. Lorenzoni, "L'architettura", cit. [cfr. note 42], p. 60.

⁵² On Dolfini's contributions to the present San Lorenzo floor plan see note 4. On the question of whether Dolfini might have intended the basilica of San Lorenzo to have either compound nave piers or freestanding nave columns, perhaps of brick (see note 41), the Basilica of San Tommaso in Pavia is a relevant precedent to examine. This imposing brick basilica, today deconsecrated, partially demolished and converted into offices, was begun c. 1400, and has a nave lined with two colonnades of six massive brick columns each. The basilica, which has no nave chapels, was built with a flat wooden ceiling, but may have originally been intended to be vaulted. The authorship is unknown, though it resembles works of Bernardo da Venezia. Thus, the Basilica of San Tommaso provides a late medieval example of a colonnaded, flat-ceilinged nave similar to both those of the Basilica of San Lorenzo in Florence and the Early Christian basilica type. On San Tommaso see: Angiola Maria Romanini, *L'architettura Gotica in Lombardia*, I, Milan 1964, p. 465. Ermanno Arslan and Maria Grazia Bossi, "La chiesa di S. Tommaso in Pavia nella sua ambientazione urbanistica", *Atti del convegno si studio sul centro storico di Pavia, 4-5 luglio 1964*, Pavia 1968, pp. 305-311.

⁵³ For *trecento* evidence of the 16 br. *milanesi* grid of the Cathedral of Milan floor plan, see the letter and diagram of the late fourteenth century mathematician Stornaloco. Paul Frankl, "The Secret of the Mediaeval Masons", *The Art Bulletin*, XXVII, 1, 1945, p. 53. For documentary and observation-based evidence of the 11 br. *florentine* grid of Santo Spirito see Leonardo Benevolo, Stefano Chieffi and Giulio Mezzetti, "Indagine sul S. Spirito di Brunelleschi", *Quaderni dell'istituto di storia dell'architettura*, XV, 85-90, 1968, p. 4; and Appendix 9.3.

⁵⁴ The Gothic-period sketchbook of Villard de Honnecourt contains a simple sketch of a grid-based cathedral floor plan that resembles both those of the Cathedral of Milan and the Basilica of Santo Spirito. The caption inscribed below the sketch reads: "This is a square church designed for the Cistercian Order", thus indicating a possible, ultimate source of these plans. The word "square" in

this context perhaps refers to the regular grid. Theodore Bowie, ed, *The Sketchbook of Villard de Honnecourt*, Bloomington and London, 1959, pp. 92-93, Plate 41.

⁵⁵ In 1922 Fontana noted that the Cathedral of Pisa had long been believed to have suggested to Brunelleschi both the general form of the Santo Spirito floor plan, and the idea of continuing the colonnades around the transept arms and apse. Fontana, “Il Brunelleschi” [cfr. note 11], p. 173.

⁵⁶ In contrast to Manetti’s warning pertaining to the basilica of San Lorenzo that “[...] stimandosi di Filippo, si stimerebbe el falso, e non v’è punto drento l’onore suo” (“[...] judging it as Filippo’s would be to judge falsely, because his honor is not in it”; Manetti, *Vita*, cit. [cfr. note 1], p. 111), regarding Santo Spirito Manetti notes that Brunelleschi himself commented with satisfaction “[...] gli pareva avere posto una chiesa secondo la sua intenzione in quanto al composto dello edificio” (“[...] that it seemed to him that he had founded a church according to his intention, as far as the arrangement of its parts was concerned”; Manetti, *Ivi*, pp. 123-124). Manetti furthermore tells us that Brunelleschi documented his Santo Spirito design with “un modello di legname a braccia piccolo” (“a wooden scale model”; Manetti, *Ivi*, p. 122), and that in overseeing the first phase of construction, which probably began around 1436, “E certamente se del modello e’ non si usciva” (“[...] certainly he did not depart from the model [...]”; Manetti, *Ivi*, p. 124). Evidence suggests that even decades later, this model was still respected as the authoritative record of the master’s design. A document of 1477 pertaining to the activity of the construction workers notes, for example, “[...] si seguissi il modello di Filippo in tutto” (“[...] they say that they followed Filippo’s model completely”). Carlo Botto, “L’edificazione della Chiesa di Santo Spirito in Firenze”, *Rivista d’arte*, XIII, 1931, pp. 501-502). For documentary evidence of construction as early as 22 March 1436 (modern style), see Eugenio Luporini, *Brunelleschi: forma e ragione*, Milan, 1964, p. 231, Doc. 2. Francesco Quinterio, “Un tempio per la Repubblica: la chiesa dei SS. Maria, Matteo, e dello Santo Spirito in Firenze: dal primo nucleo duecentesco al progetto brunelleschiano,” *Quaderno dell’Istituto di storia dell’architettura*, 1990, no. 15-20, p. 307. Francesco Quinterio, “Il cantiere della chiesa: il vestibolo e la sagrestia,” in *La chiesa e il convento di Santo Spirito a Firenze*, Cristina Acidini Luchinat, ed., Florence, 1996, p. 109.

⁵⁷ According to my partial survey of the Carmine of Pavia and my complete survey of the Basilica of Santo Spirito, the column diameters of the Carmine (both 91.1 cm, in the sample measurements in Figure 5-7) are 2-3 cm thicker than those of Santo Spirito (88.9 cm and 87.9 cm in the sample measurements in Figure 5-8). In the Carmine, however, the clear distance between adjacent engaged column shafts that face in toward the aisles, measured in the longitudinal direction (529.9 cm in the sample measurement in Figure 5-7), is 26.5 cm less than the corresponding clear distance at Santo

Spirito (556.4 cm in the sample measurement in Figure 5-8). Thus, the Carmine column shafts are slightly thicker than those of Santo Spirito, and stand about one-third of a column diameter closer together than the corresponding columns of Santo Spirito. For the complete Santo Spirito survey, see Appendix 9.3. Brunelleschi's apparent desire to recreate the effect of perspectival foreshortening that he observed in the Carmine of Pavia thus constitutes a third possible reason for his reduction of the intercolumniations from 9 2/3 br., plinth to plinth, used at San Lorenzo, to 9 br. used at Santo Spirito. The other two possible reasons are number symbolism and site constraints. Ivi, p. 42.

⁵⁸ On this likely collaboration see Bruschi, *Filippo Brunelleschi*, cit. [cfr. note 12], pp. 78-85.

⁵⁹ Saalman, "Filippo Brunelleschi: Capital Studies", cit. [cfr. note 7], p. 127 n. 70. Note that Brunelleschi uses two steps in Santo Spirito, while Bernardo uses only one in the Carmine of Pavia. Variations of this step/plinth device are also found in the Basilica of San Petronio in Bologna, and the Old Sacristy of San Lorenzo.

⁶⁰ For illustrations and dates see James S. Ackerman, "The Certosa of Pavia and the Renaissance in Milan", *Marsyas*, V, 1947-49, p. 26 and Fig. 6. Ackerman, Postscript to "The Certosa of Pavia and the Renaissance in Milan", cit. [cfr. note 48], p. 301. Romanini, *L'architettura gotica in Lombardia*, I, cit. [cfr. note 47], p. 428-430.

⁶¹ Romanini, Ivi, pp. 509-512, 519-521, 526 n.85. Brigitte Tietzel-Hellerforth, *La facciata del Duomo di Faenza ed il problema della facciata nel Rinascimento*, Faenza 1977, pp. 330-331.

⁶² "[...] li contraforti del corpo dela giesia non hanno tuta quella grandeza che sareve de bisogno, consciderando la largheza e l'alteza dela dicta giesia, vorave se reduze la prima nave in forma de capelle cum le mezzature tra l'una capella e l'altra, cum alchuni strafiori, per li quali se porave vedere el corpo de Cristo da l'uno con l'altro de la giesia, e fazendo così vegniarevese a dare grandissima forteza ale altre tre nave per quilli archi butanti avereve più fermo el suo principio e el corpo dela giesia parerave più bello, e più con sova rexone per che el seguireve la grandeza de la cruxe": "Addi 8 maggio 1400: Bertolino da Novara — Bernardo da Venezia ingegneri", *Annali della fabbrica del duomo di Milano: dall'origine fino al presente*, I, Milan 1877, p. 213. Romanini, Ivi, pp. 415-416. Ackerman, "The Certosa of Pavia", cit. [cfr. note 60], p. 25. Ackerman, "'Ars Sine Scientia Nihil Est...'", cit. [cfr. note 31], p. 92.

⁶³ Romanini, *L'architettura gotica in Lombardia*, I, cit. [cfr. note 47], pp. 421-422.

⁶⁴ Although the minor order columns at Cerreto are too short relative to their diameters to appear classically proportioned, they currently lack bases, perhaps indicating that the floor level has been raised. Cf. Romanini, Ivi, p. 55 n. 30, 421-422. For Romanini's observations regarding a Lombard Romanesque revival in Pavia see Romanini, "L'architettura viscontea e Bernardo da Venezia", "La

certosa di Pavia dalla fondazione sino alla metà del xv secolo”, and “La chiesa di S. Maria del Carmine a Milano nella prima metà del quattrocento”, in *Storia di Milano*, VI, 1955, pp. 620-621.

⁶⁵ Double scotia column bases are found in the church of Santa Maria di Gradaro in Mantua, c. 1256-1260, but considering the short proportions of the columns their usage there appears more regionally idiosyncratic than deliberately Romanizing. Romanini, I, cit. [cfr. note 47], p. 155 and II, Tav. 58-B. On the importance of the double scotia base in the development of Renaissance architectural theory, see Howard Burns, “Baldassarre Peruzzi and Sixteenth-Century Architectural Theory”, in André Chastel and Jean Guillaume, eds., *Les traités d'architecture de la renaissance*, Paris 1988, pp. 207-226. Perhaps Bernardo da Venezia even made a sketch of Roman examples of the double scotia base in Rome itself, similar to the mid-sixteenth century sketch made by Baldassare Peruzzi, reproduced in Burns, “Baldassarre Peruzzi...”, Ivi, p. 224, Fig. 18.

⁶⁶ Saalman, “Capital Studies...”, cit. [cfr. note 7], p. 115.

⁶⁷ Another detail that reveals Brunelleschi’s intended reduction and regularization of Tuscan Romanesque forms is the down-turning architrave of the Ospedale degli Innocenti façade which, according to the fifteenth-century chronicler Antonio Billi, Brunelleschi never intended. According to Billi, when Brunelleschi had to be away during construction of the façade, his surrogate copied the detail from the Baptistery of Florence, not realizing that Brunelleschi considered that particular detail to be the one error in that building. Fabio Benedettucci (ed.), *Il libro di Antonio Billi*, Rome 1991, p. 34.

⁶⁸ See note 7.

⁶⁹ Ackerman, “The Certosa of Pavia”, cit. [cfr. note 60], pp. 23, 33.

⁷⁰ Cf. Burns’ comments regarding the concept of “Survival and Revival” in relation to antique forms in the *quattrocento*. Burns, “Quattrocento Architecture...”, cit. [cfr. note 7], p. 270.

⁷¹ Ivi, 24

⁷² Ivi, 33

⁷³ Ackerman, “The Certosa of Pavia”, Ivi, pp. 30-34. Ian Campbell, “A Romanesque Revival and the Early Renaissance in Scotland, c. 1380-1513”, *Journal of the Society of Architectural Historians* LIV, 3, 1995, pp. 302-325.

⁷⁴ In the mid-fifteenth century Flavio Biondo described the *pietra serena* columns of San Lorenzo as being of marble, thus indicating his identification of this work with ancient Roman works. Burns, “Quattrocento Architecture...”, cit. [cfr. note 7], p. 273.

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⁷⁵ Cohen, "How Much Brunelleschi?," 18-57.

⁷⁶ H.W. Janson, *History of Art: a Survey of the Major Visual Arts from the Dawn of History to the Present Day*, II ed., Englewood Cliffs, New Jersey, 1977, p. 389; III ed., 1986, p. 409; and ("radical change") VI ed., 2001, p. 397. In the current edition "radical" has been removed but the intent remains essentially unchanged: "[...] a new emphasis on symmetry and regularity distinguishes [Brunelleschi's] design for San Lorenzo [from Gothic precedents] [...]". *Janson's History of Art: The Western Tradition*, VII ed. by Penelope J. E. Davies et al., Upper Saddle River, New Jersey, 2007, p. 513.

⁷⁷ I paraphrase here John Summerson, who proposes "[...] to modify the customary view of Gothic and classic art as "opposites"; and in fact [...]" he continues, "[...] this habitual antithesis is in many ways highly unsatisfactory. It is a too obvious conclusion drawn from *prima facie* impressions". J. Summerson, "Antitheses of the Quattrocento," in Idem, *Heavenly Mansions and Other Essays on Architecture*, New York and London, W.W. Norton 1963, p. 24. For a bibliography of previous studies of the architectural proportions of the Basilica of San Lorenzo, see Cohen, "How Much Brunelleschi?," cit., Appendix 2.

⁷⁸ Rudolf Wittkower, the most influential exponent of this position, contends: "I think it is not going too far to regard commensurability of measure as the nodal point of Renaissance aesthetics. [...] While to the organic, metrical Renaissance view of the world rational measure was a *sine qua non*, for the logical, predominantly Aristotelian Middle Ages the problem of metrical measure could hardly be of similar urgency. [...] On the contrary, the medieval quest for ultimate truth behind appearances was perfectly answered by geometrical configurations of a decisively fundamental nature; that is, by geometrical forms which were irreconcilable with the organic structure of figure and building." R. Wittkower, *Architectural Principles in the Age of Humanism*, New York and London, W.W. Norton 1971, pp. 158-159. More specifically, Wittkower associates his belief in what he perceives as "[...] the metrical discipline of buildings like S. Lorenzo or S. Spirito [...]" with his belief that those buildings contain mathematically rational sets of proportions in his highly influential article: Idem, Brunelleschi and "Proportion in Perspective," *Journal of the Warburg and Courtauld Institutes* 16, 3/4, 1953, p. 289.

⁷⁹ For this attribution see Cohen, “How Much Brunelleschi?,” cit., pp. 41-44; and Idem, *Matthew Cohen’s Reply* to Letter to the Editor by Volker Herzner, “Journal of the Society of Architectural Historians”, LXVII, 4, 2008, pp. 634-635. In the present study I use the terms ‘architect’ and *capomaestro* to indicate the primary designer and highest-level construction supervisor at any particular time, a double role that I believe both Dolfini and Brunelleschi filled consecutively at the Basilica of San Lorenzo (though each may have delegated day-to-day construction supervision to a surrogate). This interpretation of Dolfini’s architect status receives support from Brunelleschi’s fifteenth-century biographer, Antonio di Tuccio Manetti, who notes that Dolfini “[...] had a knowledge equal to that of other architects of the time”. Thus, by his reference to *other* architects, Manetti implies that he considered Dolfini to be an architect as well. A. Manetti, *Vita di Filippo Brunelleschi*, ed. by G. Tanturli, Milan, Edizioni il Polifilo, 1976. p. 106. On the varied meaning of the term “architect” during the medieval period see N. Pevsner, *The Term Architect in the Middle Ages*, “Speculum”, 1942, pp. 549-562.

⁸⁰ For a previous study of the interior proportions of this basilica, which makes use of neither measurements nor available documents, see L. Gori-Montanelli, “Il sistema proporzionale dell’interno del duomo di Firenze,” in *Festschrift Ulrich Middeldorf*, ed. by Herausgeben von Antje Kosegarten and Peter Tigler, Berlin 1968, pp. 64-72.

⁸¹ On the possible role of similar late-medieval, slightly pointed arches in Dolfini’s design for the Basilica of San Lorenzo prior to Brunelleschi’s modifications, see Cohen, “How Much Brunelleschi?,” cit., p. 42.

⁸² B. Sansone Sgrilli, *Descrizione e studi dell’insigne fabbrica di S. Maria del Fiore*, Florence, Bernardo Paperini 1733 [rpt. Florence 1996], figs. II and IV; and G. Rocchi et al., *S. Maria del Fiore. Il corpo basilicale. Rilievi, documenti, indagini strumentali. Interpretazione*, Milan, Ulrico Hoepli 1988, tav. 1-2. The drawings published by Sgrilli and Rocchi et al. show slight variations in the nave arcade bay widths, but smaller and distributed differently than the actual variations. These previously-published dimensional variations are probably unintentional graphic distortions resulting from the publication process. Rocchi et al. note a slight narrowing of the central nave from west to east, and slight trapezoidal distortions in some of the nave bays, but make no mention of significant bay width irregularities. *Ibidem*, tav. 2, caption. Although Rocchi et al. present a large, detailed floor plan annotated with hundreds of measurements, none of them are useful for proportional analysis because virtually all of them are triangulations between points of measurement randomly located on the pavement, away from corners, edges and central axes of architectural features. *Ibidem*, tav. 2.

⁸³ Uzielli claims that on 18 April 1896 he measured, with the help of a certain carpenter Gabriello Bencini, two inter-axial distances between unspecified nave piers in the longitudinal direction, and two more in the transverse direction. He then claims to have taken the average of each pair of measurements, converted them to Florentine *braccia* using the nineteenth-century value for the *braccio* of 58.36 cm, and compared them to the corresponding dimensions noted in a cathedral document of 1357. Although he provides neither measurements nor calculations, he claims that his measurements correspond precisely to the 1357 specifications, within 1 mm, because the 1357 specifications produce a metric value for the Florentine *braccio* in use in 1357 of 58.35 cm. He thus deduces that the Florentine braccio remained invariable during the intervening centuries. Uzielli's story is probably invented, for given the large variations in the distances between the nave piers (both longitudinal and transversal), no combination of measurements would produce the results he reports, much less within 1 mm of discrepancy; and in any case he would have been remiss in failing to report the substantial variations in the inter-axial distances that he would have discovered if indeed he had undertaken the survey he describes. G. Uzielli, *Le misure lineari medioevali e l'effigie di Cristo*, Florence, Bernardo Seeber, 1899, pp. 13-14.

⁸⁴ I began the Santa Maria del Fiore survey in June 2005 with a steel tape measure manufactured by SEB, and continued it in June 2008 using a Leica Disto A5 laser measuring device. In 2008 I checked many of the 2005 measurements with the laser and found the results to be very consistent, with discrepancies in the range of 0-8 mm. I measured some of the vertical dimensions from a mobile scaffolding provided by the *Opera* of Santa Maria del Fiore, and others from the upper gallery (*ballatoio*).

⁸⁵ In this study one Florentine *braccio* is assumed to measure 58.36 cm. When no simple fractional equivalent for a partial *braccio* is implied, such remainders are expressed in modern English decimal notation. Cfr. Cohen, "How Much Brunelleschi?," cit., pp. 27 and 53 note 50.

⁸⁶ "Seguasi fino poste le due colonne et volti gli archi, et inanzi che vada più inanzi se n'abi consiglio." *Santa maria del Fiore. La costruzione della chiesa e del campanile*, ed. by C. Guasti, Florence, Loescher & Seeber 1887, p. 82.

⁸⁷ *Ibidem*, p. 84.

⁸⁸ "E che e' s'intenda essere di spazio da meza cholonna a meza cholonna br. xxxiiij $\frac{3}{8}$ $\frac{1}{1}$ per lo largho. E per lo lungho br. xxxiiij. Di che seguitano iij volte l'una dopo l'altra per lo lungho da meza colonna a meza colonna per largho br. trentatre e tre ottavi e mezo: per lo lungho, br. trentaquattro, da meza a meza cholonna". *Ibidem*, p. 94. Note that consistent with fourteenth and fifteenth-century documents, in my translation I have transcribed the fractions with horizontal bars instead of Guasti's

diagonal slashes. I have not been able to verify the actual form used in the cathedral archives in question.

⁸⁹ The nave pierplinths are roughly Greek Cross shaped. The plinths of Piers 1-3 and 8-10 (Figure 5-18) measure nearly exactly 5 br from end to end, in both the east-west and north-south directions. Those of Piers 4-7 measure about 5.19 br. Since the latter were built in what were most likely the later phases of nave construction (see below), I will assume that the 5 br plinth dimension is the one originally intended.

⁹⁰ In the south nave arcade, the westernmost bay measures 1692.1 cm, which exceeds 29 br (1692.44 cm) by a negligible 3.4 mm. The corresponding bay in the north arcade measures 1690.6 cm, or just 1.8 cm less than exactly 29 br (Figure 5-18).

⁹¹ Toker suggests that the fourth bay may have been added in order to achieve metrical superiority over the Cathedral of Siena. M. Toker, "Florence Cathedral: the Design Stage," *Art Bulletin* 60, 2, 1978, pp. 226-227; and Idem, "Arnolfo's S. Maria del Fiore: A Working Hypothesis," *Journal of the Society of Architectural Historians* 42, no. 2, 1978, p. 104ff. Trachtenberg proposes that the fourth bay was added in order to bring the total interior nave length (assuming four ideal bays measuring 34 br on center, plus the 8 br inner faces of the western crossing piers) to 144 br, and therefore into conformance with a "proportional chain" of numerical relationships that he identifies. M.

Trachtenberg, "Architecture and Music Reunited: A New Reading of Dufay's" *Nuper Rosarum Flores* and the Cathedral of Florence," *Renaissance Quarterly* 54, no. 3, 2001, pp. 751-754. On the basilica construction history see also H. Saalman, "Santa Maria del Fiore: 1294-1418," *Art Bulletin* 46, no. 4, 1964, pp. 471-500.

⁹² Toker, *ibidem*, 1983, p. 108ff. Franklin Toker has indicated to me that while he believes, based on available documentary evidence, that Arnolfo started construction simultaneously from both the west and the east in 1293, he has never thought that true of Talenti and his contemporaries half a century later.

⁹³ One apparently intentional architectural refinement in this basilica is the gradual narrowing of the nave width from 28.57 br (1667.5 cm) at the interior façade, to 27.93 br (1630.0 cm) at the entrance to the octagon; a difference of nearly $\frac{2}{3}$ br (0.64 br), or, 37.5 cm (Figure 5-18); also noted by Rocchi et al., in *Santa Maria del Fiore* cit., tav. 2, caption (see note 9, above). No such narrowing is indicated in the surviving documents of the *Opera*, however, which simply specify that the central nave was to measure $33\frac{1}{2}$ br on center (measured north to south). Therefore, this refinement appears

to have been added (perhaps on site by the masons) after the official dimensional specifications were established. See discussion of the dimension $33\frac{1}{2}$ br below, and Cohen, “How Much Brunelleschi?” cit., p. 54 note 62.

⁹⁴ The ten nave pier shaft heights are very consistent from one to the next (Figures 5-19 and 5-21). The maximum variation is 6.3 cm, but the more useful calculation for evaluating the extent of the variation in these pier shaft heights is the standard deviation, which is a mere 1.84 cm. While a calculation of the mean (average) pier shaft height is not, strictly speaking, a mathematically sound basis for a proportional analysis, considering the small number of pier heights in question and the low standard deviation, the mean does not differ much from each individual nave pier height, and so serves as a reasonably accurate representative for all ten pier heights.

⁹⁵ Thus, the progression $1\frac{2}{3}$, $(5\frac{2}{3})$, $9\frac{2}{3}$, $13\frac{2}{3}$, $17\frac{2}{3}$, must be read as 1, (5,) 9, 13, 17. The numbers shown in parentheses are reconstructions. Cohen, “How Much Brunelleschi?” cit., pp. 27-28.

⁹⁶ The dimension 41 br equals 2392.76 cm. Of the ten upper pier shaft heights in the nave (Figure 5-20 and 5-21, Dimension B as indicated in Figure 5-19), five of them are from 2-7 cm taller than 41 br, and four are from 2-4 cm shorter. The remaining height (Pier 3), which is 15.3 cm taller than 41 br (2392.76 cm), is aberrational perhaps due to construction or measurement error.

⁹⁷ The ratio 29:41 approximates the ratio $1:\sqrt{2}$ within 0.03%. Cohen, “How Much Brunelleschi?” cit., p. 32.

⁹⁸ See note 22 above.

⁹⁹ Cohen, “How Much Brunelleschi?” cit., pp. 33 and 53 note 42.

¹⁰⁰ The treatise was translated in the mid-fifteenth century by Marsilio Ficino for Cosimo de' Medici, but could have arrived in Florence earlier; for example, at the end of the fourteenth century when the Ottoman Turks encroached into Byzantine territory and Greek-speaking men of learning took refuge in Italy. *Ibidem*, p. 32.

¹⁰¹ Cohen, “How Much Brunelleschi?” cit., pp. 21-24.

¹⁰² See Chapter 6.2.

¹⁰³ “Che il fondamento delle cholonne dallo spazo in giù si faccia br. vij per ognie verso, quadro, fino alla buona ghiaia entro l'aqua”. *Santa Maria del Fiore*, ed. by Guasti cit., p. 94.

¹⁰⁴ Cohen, “How Much Brunelleschi?” cit., pp. 28, 33-37.

¹⁰⁵ Cohen, “How Much Brunelleschi?” cit., p. 32.

¹⁰⁶ S. Serlio *Il quinto libro d'architettura* [...] *nel quale si tratta di diverse forme de'tempj sacri*, Paris 1547, fol. 2v. The Vitruvian passage to which Serlio refers is probably *de Architectura*, III.iv.1. In it, however, Vitruvius notes that walls supporting columns should be "[...] thicker by one half than the columns [...]", and thus denotes the ratio $1:1\frac{1}{2}$, not $1:\sqrt{2}$.

¹⁰⁷ The San Lorenzo nave arcade bay set of proportions embodies geometrical precision in the overlap of the square, root-2 rectangle and dual diagonal, when all three figures are drawn to touch the nearer and farther edges of adjacent column plinths (Figure 4-12). It embodies mathematical precision in the approximation of the ratio $1:\sqrt{2}$ with the ratio $9\frac{2}{3} : 13\frac{2}{3}$, which is accurate to within 0.03% (3 mm at the scale of the San Lorenzo nave arcades), or, more than ten times more accurate than the most accurately constructed masonry work in that basilica. Cfr. Cohen, "How Much Brunelleschi?" cit., p. 32.

¹⁰⁸ In the San Lorenzo nave arcade bay set of proportions, when a square and root-2 rectangle are drawn to touch the edges of two adjacent column plinths, their top lines overlap perfectly (Figure 4-12). Probably due to construction error, however, the heights of the column shafts are taller than the top of this overlapping figure by 11-12 cm. See Chapter 2 and Cohen, "How Much Brunelleschi?" cit., pp. 33-37. In the Santa Maria del Fiore nave arcade bay set of proportions, by contrast, when an overlapping square-and-a-half and two-square rectangle are drawn to touch the edges of two adjacent nave pier plinths, their top lines fail to overlap by 9.75 cm. The tops of the nave pier shafts arrive precisely in the middle of this gap.