Abstract. Thomas Jefferson dedicated his later years to establishing the University of Virginia, believing that the availability of a public liberal education was essential to national prosperity and individual happiness. His design for the University stands as one of his greatest accomplishments and has been called "the proudest achievement of American architecture." Taking Jefferson's design drawings as a basis for study, this paper explores the possibility that he incorporated incommensurable geometric proportions in his designs for the Rotunda. Without actual drawings to illustrate specific geometric constructions, it cannot be said definitively that Jefferson utilized such proportions. But a comparative analysis between Jefferson's plans and Palladio's renderings of the Pantheon (Jefferson's primary design source) suggests that both designs developed from similar geometric techniques.

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An American Vision of Harmony: Geometric Proportions in Thomas Jefferson's Rotunda at the University of Virginia

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*...and in his hand
He took the golden compasses, prepared
In God's eternal store, to circumscribe
This universe, and all created things…*

--Milton, *Paradise Lost*, Book VII, quoted in "*Thoughts on English Prosody*" by Thomas Jefferson to Chastellux, October 1786 [Peterson 1984, 618].

INTRODUCTION

Thomas Jefferson died on July 4, 1826, fifty years after the adoption of the Declaration of American Independence, desiring in his 1826 inscription for his tombstone to be remembered as its author, the author of Virginia's Statute for Religious Freedom, and the father of the University of Virginia [Peterson 1984, 707]. The first two accomplishments fixed the causes of freedom and self-determination at the heart of the American ethic. The third provided public higher education for the common man, while standing for all time as a great architectural achievement.

Jefferson dedicated the last years of his life to establishing the University of Virginia and to designing its campus and buildings. It was his last great endeavor, expressing his hopes for the nation's future: "the last act of usefulness

I can render, and could I see it open I would not ask an hour more of life" (Jefferson to Spencer Roan, March 1821[Mayo 1970, 336]). The "academical village," as he called it, achieves a unique architectural vision of harmony, adapting timeless, classical mathematical rules of design and proportion to a specific American context. In 1976 the American Institute of Architecture proclaimed Jefferson's campus to be "the proudest achievement of American architecture in the past 200 years" [Ellis 1997, 280].

THE UNIVERSITY OF VIRGINIA CAMPUS

The University project was central to Jefferson's vision for a total system of primary, intermediate and university education, first proposed in his 1779 "Bill for the More General Diffusion of Knowledge." Jefferson secured land for the campus, selecting an elevated 28-acre site in the rural countryside near Charlottesville. He then designed the grounds and buildings in the classical European style for a community of ten faculty scholars and two hundred students, adapting the ancient Roman villa to an American pastoral setting.

Jefferson first proposed the idea of the university as a village in a letter dated January 5, 1805, to L.W. Tazewell of the Virginia State Legislature, suggesting that the university be housed in a village rather than one large building [Peterson 1984, 1152]. (Jefferson first used the term "academical village" in a letter dated 6 May 1810 to Hugh L. White and other trustees of East Tennessee College [Peterson 1984, 1222-1223].) Between 1814 and 1817, he developed a series of pavilions connected by a continuous colonnade around three sides of a lawn, leaving the fourth side open for future expansion. Eventually, this became the University of Virginia Lawn. In 1817, Jefferson solicited ideas for the University from Dr. William Thornton, the amateur-architect for the U.S. Capitol, and from Benjamin Henry Latrobe (Jefferson to William Thornton, 9 May 1817, and Jefferson to Benjamin Henry Latrobe, 12 June 1817 [Jefferson 1992]). Latrobe was the English-born architect who, as surveyor of public buildings, contributed significantly to the Capitol project. Latrobe's American commissions also included the Bank of Pennsylvania and the Baltimore Cathedral [Norton 1976, 196-227].

Thornton replied with two sketches and recommendations for pavilion façades, which Jefferson incorporated into the final plan. Likely, it was Thornton who first proposed a dominant central building. Latrobe suggested that Jefferson transform the center pavilion at the north end of the Lawn into a monumental building with a hexastyle portico. He proposed a Roman dome over a circular lecture room above, with additional rooms below. But it was Jefferson's idea to pattern the eventual Rotunda after the Pantheon, and to make it a library. Latrobe also provided pavilion façades and persuaded Jefferson to adopt a single colossal order instead of stacking orders over two stories. At the time, Latrobe was evolving his own U-shaped plans for a military academy, a marine hospital and a national university, but he found Jefferson's village plan to be "entirely novel" [Latrobe to Jefferson, 17 June 1817, as quoted in Woods 1985, 281].[1]

The scheme remains today essentially as Jefferson conceived it, a U-shaped configuration of buildings laid around a lawn of three terraces that slope gently to the south. The Lawn, as it is called, is tree-lined, measuring 740' long by 192' wide [*World Heritage List Nomination* 1987, 3a].[2] At the northern end stands a domed Rotunda. On the east and west, two rows of five pavilions each occupy the long sides of the Lawn (**Fig. 1**). Originally, the south end permitted a view of the mountains beyond, but it was enclosed in 1896 by three classroom buildings designed by New York architect Stanford White.

Jefferson strove continually to reconcile beauty and practical utility, a goal he met with great success at the University of Virginia. To accommodate separate schools comprised of faculty quarters and classrooms, he designed ten pavilions, numbered I through X, assigning odd numbers to the west row and even numbers to the east. The pavilions are connected by dormitory rooms housing two students each. A continuous undercover passage or *loggia* offers weather protection and "communication along the whole range" (Jefferson, "Report of the Commissioners for the University of Virginia, 4 August 1818 [Peterson 1984, 458]). A single-story Tuscan colonnade, modeled after the White House colonnade in Washington, D.C., unites the structures along each row. Behind these inner ranges of pavilions and dormitories are parallel outer ranges with additional student rooms and six hotels. The hotels, created originally as dining halls, now serve as offices and meeting spaces for the University. Between the inner and outer ranges, serpentine shaped brick walls enclose gardens for faculty and students.

The ten academic pavilions within this ensemble contain classrooms and faculty residences, providing areas for living and learning and for privacy and public discourse. The pavilions also serve as physical models for the study of classical architecture, designed according to classical rules of building that had been in practice since antiquity. The different pavilions draw from a rich vocabulary of classical forms and follow similar rules of proportion. However, no two buildings are alike, so that each may present a distinct lesson in the classical style. Jefferson proposed in 1817 that the pavilions "should be models of taste and good architecture, and of a variety of appearance, so as to serve as specimens for the Architectural Lectures" (Jefferson to William Thornton, 9 May 1817 [1992]). Of the University's ten pavilions, four are in the Doric order, four are in the Ionic order, and two are in the Corinthian order.

Standing in complement to the cubic architecture of the academic pavilions is Jefferson's domed Rotunda, begun in 1822 and completed for the most part in 1826, the year Jefferson died. The Rotunda provides a fitting centerpiece for the scheme. It is entered from the Lawn through a Corinthian hexastyle portico that supports a single triangular pediment (**Fig. 2**). Inside, a domed top floor housed the University library, which now serves as a meeting hall. The two stories below contain ovoid rooms for classes and other meetings.

Jefferson patterned the University Rotunda after Hadrian's Pantheon of ancient Rome, although he reduced the dimensions by half and built with native red brick instead of stone. In fact, the original Pantheon was a monument to Imperial Rome, but Jefferson believed it to be the achievement of the Roman Republic and the finest example of spherical architecture.[3] Hadrian's Pantheon was also a sanctuary, its sacred sphere uniting antiquity's vast array of gods and deities. But to express the central importance of education to a just and free society, Jefferson transformed the ancient temple into a library, advancing reason instead of divine revelation, and replacing the gods of the original temple with books he selected. He situated the Rotunda at the prominent northern end of the Lawn, where a chapel or church normally stood at other campuses.

ARCHITECTURAL AND MATHEMATICAL SOURCES

To produce a university campus in the classical style, Jefferson looked both to architectural and mathematical sources, which he viewed as interrelated. (In the "Report of the Commissioners for the University of Virginia," 4 August 1818, the university curriculum that Jefferson devised joined architecture with algebra and geometry, under the category of applied forms of mathematics [Peterson 1984, 462].) He held a special regard for mathematics throughout his life, nurtured from early years of study at the College of William and Mary with his lifelong friend and mentor William Small.[4]

Prior to Small's tenure at William and Mary, mathematics was restricted to the barest rudiments of algebra, geometry, surveying and navigation. Professor Small elevated the sciences to a new level of prominence, with mathematics at the core [Bedini 1990, 27]. When Jefferson later devised the University of Virginia curriculum, he followed Small's example, promoting mathematics more than was typically done at other American colleges [Smith 1947, 51].

"When I was young, mathematics was the passion of my life," Jefferson once recalled.[5] About the time he conceived his "academical village," his early passion was rekindled on the occasion of tutoring his grandson: "I have resumed that study with great avidity. It was ever my favorite one. We have no theories there, no uncertainties remain on the mind; all is demonstration and satisfaction" (Jefferson to Benjamin Rush, 17 August 1811 [Ford 1904-05, XI: 212]).

Jefferson was proficient in a wide range of mathematical disciplines, including arithmetic, algebra, geometry, trigonometry and fluxions, or Newtonian calculus, and as well their applications to navigation, surveying, astronomy, geography and other mechanical and natural sciences. Rather than study mathematics for its own sake, he endeavored to apply his knowledge in tangible ways, whether by using astronomical observations to calculate navigational longitude, by creating a decimal system for the nation's coinage, or by employing the principles of fluxions in the design of a plow [Cohen 1995, 101-102, 293-295; Smith 1947, 49-70]. At the University of Virginia, he utilized mathematics to survey the Lawn and its buildings, then calculated how to adapt the dome of the Rotunda to serve as an astronomical observatory (Jefferson, Specification Book for University of Virginia, 18 July 1819, 2, N-318 [O'Neal 1960, 52-53, doc. 94; Nichols 1961, 39; Jefferson 1995b]).

Geometry, which he explored in both planar and spherical configurations, held special interest. His library included numerous contemporary studies on the subject, as well as classical texts such as the *Elements* of Euclid, the *Works* of Archimedes, and a *Commentary on the First Book of Euclid's Elements* by Proclus, the fifth century, A.D., Neoplatonist [Sowerby 1952, IV: 20-26]. Jefferson believed that geometry, to be understood and appreciated, should be drawn by hand in the form of spatial constructions. While serving as American Minister in

Paris, he corresponded with mentor and friend George Wythe about fabricating a set of geometrical models for teaching aids: "I should think wood as good as ivory: & that in this it might add to the improvement of the young gentlemen; that they should make the figures themselves" (Jefferson to George Wythe, 16 September 1787 [Ford 1904-05, V: 338-341]).

This hands-on approach to geometry and other mathematics likely shaped his architectural pursuit, as did a variety of classical studies. Jefferson's designs for the University of Virginia campus came largely out of the eighteenth-century Neo-classical movement that had emerged as Humanism in Europe during the Renaissance, then flourished in the Enlightenment from the 1730s to the end of the century.

Jefferson was largely responsible for bringing the classical aesthetic to America at a time when there were few real architects and where, as he said, "a workman could scarcely be found here capable of drawing an order." Desiring to bring elegance to the nation's public buildings, he asserted that to "give these symmetry and taste would not increase their cost," but "the first principles of the art are unknown, and there exists scarcely a model among us sufficiently chaste to give an idea of them" (*Notes on the State of Virginia*, 1787 [Peterson 1984, 279]). Jefferson scholar Fiske Kimball's assessment is that "directly or indirectly American classicism traces its ancestry to Jefferson, who may truly be called the father of our national architecture" [1968, 89].

Jefferson was practicing the Roman classical architecture of Andrea Palladio and of late eighteenth-century France (following, however, the Colonial convention in the use of native brick and wood) at a time when American buildings were typically "designed" by craftsmen and tradesmen, and when the English vernacular of Christopher Wren was popular in the Colonies [Kimball 1968, 18, 82]. Jefferson hoped that the classical tradition would raise the American standard of building to that of the European masters and that his "academical village" would be "a splendid establishment, would be thought so in Europe, and for the chastity of its architecture and classical taste leaves everything in America far behind it" (Jefferson to William Short, 24 November 1821 [Jefferson 1992]).

Jefferson's designs were rooted in classical ideals of beauty and harmony, yet served a nation just emerging from the American frontier. The World Heritage assessment is that Jefferson's architecture expresses his hope for a new society: that it "would be noble and free from the traditions of the Old World; that it would offer infinite possibilities to the common man; and, that it would serve as a beacon for freedom and self-determination for the world" [*World Heritage List Nomination* 1987, 5]. The University of Virginia Lawn and Jefferson's Monticello residence were designated World Heritage sites in 1987.

Yet Jefferson remained faithful to the rules and forms of antiquity as a point of origin. Like the State Capitol building in Richmond, which Jefferson helped to design, the University pavilions and hotels recreate the classical temple form with its strict vocabulary of pediments, entablatures, columns and orders. The designs follow mathematical rules of symmetry and proportion, which developed from ancient times.

An "amateur" architect with no formal training, Jefferson first became aware of classical architecture through books.[6] His earliest acquired titles probably included Giacomo Leoni's *The Architecture of A. Palladio*, James Gibbs's *Rules for Drawing the Several Parts of Architecture* and *A Book of Architecture*, and the posthumously published *Settimo Libro* (Book VII) of Sebastiano Serlio's *Trattato di architettura* (*On Architecture*) [O'Neal 1978, 137, 140, 267, 322; Kimball 1968, 94, 97].

Later, he gained first-hand experiences of ancient Roman and eighteenth-century French buildings, during his tenure as American Minister to Paris between 1784 and 1789. When Jefferson arrived in Paris, the pure visionary designs of Etienne-Louis Boullée and Claude-Nicolas Ledoux dominated the French architectural scene. Jefferson admired Boullée and Ledoux for their use of geometric forms, and employed cubical, spherical, cylidrical, and "octangular" volumes, both as terms in his writings and as forms in his own designs [Pickens 1975, 259]. It has also been asserted that Jefferson's Rotunda descends from the spherical conceptions of Ledoux and Boullée; like Boullée's cenotaph to Newton, Jefferson intended to illuminate the Rotunda ceiling with stars "to extend the symbolism of the dome as the canopy of heaven" [Nichols 1976, 175-176, 180-81].

Jefferson especially enjoyed the Parisian style *hôtels* and pavilions and saw, in facades such as the Galerie du Louvre, the Hôtel du Garde-Meuble, and the two fronts of the Hôtel de Salm, potential models for public buildings soon to be erected in Washington. While abroad, he visited the ancient Roman temple Maison Carrée at Nîmes in France, which he counted among the "most perfect examples of cubic architecture," and used later as a prototype for the Virgina State Capitol at Richmond.[7]

Jefferson never actually saw the Pantheon in Rome, his model for the University Rotunda, but he knew various studies of the ancient temple by Palladio, Giovanni Piranesi, Antoine Desgodetz and others. Orders for the University pavilions were selected from drawings of ancient buildings published by Palladio and Roland Fréart de Chambray.[8]

MATHEMATICAL SYSTEMS OF PROPORTION

Jefferson studied the written treatises of Marcus Pollio Vitruvius, Leon Battista Alberti, Inigo Jones, Serlio, Palladio and others who relied on classical rules of architecture and mathematical techniques for achieving proportion. Classical architectural theories derived essentially from philosophies of unity and harmony. Alberti's fifteenth-century masterwork *De re aedificatoria* (*On the Art of Building in Ten Books)* proposes that beauty arises from "sympathy and consonance," the result of a natural law which the author calls *concinnitas* and whose task it is "to compose parts that are quite separate from each other by their nature, according to some precise rule, so that they correspond to one another in appearance" [Alberti 1988: IX, v, 302-303]. The natural principle of *concinnitas* may apply in building design to the measures of cities and houses or to considerations of scale, seasonal variations, temperature and location. In each instance, "the parts ought to be composed that their overall harmony contributes to the honor and grace of the whole work, and that effort is not expended in adorning one part at the expense of all the rest" [Alberti 1988: I, ix, 23].

In similar fashion, Palladio's *I quattro libri* (*The Four Books on Architecture*) offers a vision of harmony that encompasses every aspect of built and natural form, from the application of mathematical proportions in measured plans to organic methods of land use planning and siting. Following Vitruvius, he asks that architectural works be useful, durable and beautiful. To achieve beauty, they should be built "with such proportions that together all the parts convey to the eyes of onlookers a sweet harmony" [Palladio 1997: IV, Foreword, 213].

WHOLE NUMBER RATIOS AND MUSICAL HARMONY

While classical theorists from antiquity through the Enlightenment provided the philosophical framework for a unified architecture, they also supplied mathematical techniques for achieving harmony and proportion in specific works. Jefferson, himself a musician, was acquainted with the Pythagorean system associating whole number ratios with audible musical sound; the rudiments of Pythagorean theory are outlined in Montucla's *Histoire des Mathématiques*, which Jefferson owned and recommended [Montucla 1968, I: 125-142; Sowerby 1952, IV: 15] (Jefferson to John Minor, 30 August 1814 [Ford 1904-05, XI: 421; Jefferson 2000]). Pythagoras had discovered the relationship between simple whole numbers -- 1, 2, 3 and 4 -- and the fundamental consonant intervals of the Greek musical scale -- the octave, the fifth and the fourth. He also realized that number ratios associated with audible sound vibrations could be measured in space.

The application of music's mathematical laws to architectural design developed through antiquity into the Renaissance and the Enlightenment. Vitruvius, in *De architectura* (*Ten Books on Architecture*), observed the numbers of musical harmony in nature and the human body, and recommended their use in the proportions of various orders and other elements of building plans [Vitruvius 1999: III, i, 47]. Following Vitruvius, theorists such as Alberti and Palladio outlined methods for constructing five orders used by the ancients -- Tuscan, Doric, Ionic, Corinthian and Composite -- according to the whole number ratios of musical consonance [Palladio 1997: I, xii-xviii, 17-54; Serlio 1996: IV, 254-259 (fol. iii-v); Alberti 1988: IX, vii, 309].

THE PROPORTIONS OF GEOMETRIC FIGURES

Renaissance scholar Rudolf Wittkower has written extensively about the mathematics of musical harmony and its application to the classical orders and other elements of building design. Jefferson scholars Kimball, William O'Neal and others have explored Palladio's method for drawing the orders and its influence on the proportions of Jefferson's buildings. Joseph Lasala has analyzed the University Pavilions according to the Palladian system of dividing a module, based on the lower diameter of a column, into minutes and seconds. From this are derived an order's six major components: the base, shaft and capital of the column; and the architrave, frieze and cornice of the entablature. The order, once determined, fixes the size and distribution of other building components.[9]

Jefferson owned numerous volumes pertaining to whole number methods for constructing the orders. Beside Vitruvius, Serlio, Alberti and Palladio, his library included studies by Giacomo Barozzio da Vignola, Vicenzo Scamozzi, Claude Perrault, Fréart de Chambray and others [O'Neal 1978, 22-24, 117-119, 132-133, 281-285, 312-319, 360-363, 367-370]. But these were not the only systems of proportion available to architects in Jefferson's day. Jefferson was no doubt familiar with techniques for achieving harmony through incommensurable ratios associated with elementary geometric figures.

Jefferson's designs regularly feature geometric shapes and volumes. The plans for his Monticello residence and Poplar Forest retreat present octagonal and semi- and elongated-octagonal figures.[10] The University Rotunda, whose dome he describes as a "sphere within a cylinder" (Jefferson to William Short, 24 November 1821 [Jefferson 1992]), presents an array of circles, squares and triangles.

But geometric shapes may have contributed beyond their use as forms. This paper presents a detailed analysis, suggesting that Jefferson applied the proportions inherent in geometric figures. Unfortunately, specific geometric studies of the Rotunda do not appear among Jefferson's extant sketches, but one may analyze his design sources for evidence of these proportions, and then compare the results with his own designs.

THE UNIVERSITY ROTUNDA AND THE LEONI *PALLADIO* PANTHEON COMPARED

Jefferson's description of the Rotunda, written in 1825 to accompany Peter Maverick's engraving of the University ground plan, reads: "The ROTUNDA, filling up the Northernmost end of the ground is 77 feet in diameter, and in height, crowned by a Dome 120 deg. of the sphere. The lower floor has large rooms for religious worship, for public examinations, and other associated purposes. The upper floor is a single room for a Library, canopied by the Dome and it's sky-light [*sic*]" ("An Explanation of the Ground Plan of the University," 3 March 1825) [O'Neal 1960, 1-2]).[11]

Jefferson's primary source for the Rotunda was the Pantheon of Rome published in Leoni's 1721 translation of *Palladio*, which served throughout the design and building process [O'Neal 1960, 2] (**Fig. 3**). Possibly, Jefferson took the name "Rotunda" from the Leoni *Palladio*, which says: "Of all the Temples which are to be seen in Rome, none is more famous than the Pantheon, at present call'd [*sic*] the Rotunda…. The height of it from the floor to the opening at the top, (whence it receives all its light) is the diameter of its breadth from one Wall to the other…" [Leoni 1742, II: IV, xx, 28].

Jefferson's Rotunda compares with the Pantheon in significant ways. The Rotunda's overall diameter of 77 feet is one-half that of the Pantheon, producing an area of one-quarter and a volume of one-eighth the original. Jefferson himself wrote: "The diameter of the building 77. feet, being 1/2 that of the Pantheon, consequently 1/4 it's area, & 1/8 it's [*sic*] volume. the Circumference 242.f." (Notes on drawings for Rotunda, N-331[O'Neal 1960, 50, doc. 93; Nichols 1961, 39; Jefferson 1995b]).

The Pantheon illustrated in the Leoni *Palladio* features a hemispherical dome whose interior, in section, conforms to a circle. The circle's vertical diameter measures the distance between the floor and the oculus. Its horizontal diameter measures the distance within the interior circular wall (**Fig. 4**). Meanwhile, Jefferson's Rotunda, in section, traces a circle along the exterior surface. The circle is tangent to the basement floor, which lays two stories below, underground (**Fig. 5**). The result is that the Pantheon's single-storied interior is relatively greater in height than the Dome Room of the University Rotunda.

Jefferson's exterior view of the dome includes a dotted circle, which follows the dome and is tangent to the outside walls and to the baseline (see **Fig. 2**). This is not the case with the Pantheon, where a circle traced by the dome falls inside the exterior walls and below ground (see **Fig. 9**). The result is that the exterior of Jefferson's Rotunda fits neatly within a square, while the Pantheon appears more low and wide (both the Rotunda and the Pantheon are raised by a flight of stairs, but the reduced scale of the Rotunda results in stairs of steeper appearance).

The Pantheon features a Corinthian, octastyle portico, with three bays on the ends. The Rotunda's south-facing portico is Corinthian, but hexastyle. The portico of the Pantheon presents two pediments, while Jefferson's Rotunda has only one (it is noteworthy that Serlio's rendition of the Pantheon features a single pediment [see Serlio 1996: III, 102 (fol. viii)]). The Pantheon contains two sets of triangular stairs between the portico and the sanctuary. In Jefferson's Rotunda, the stairs are enlarged and repositioned within the main body of the building (compare **Fig. 6** and **Fig. 8**).

The interior of Jefferson's Rotunda differs substantially from the Pantheon. The Pantheon presents a single, open circular story, whereas the Rotunda divides into three separate floors.[12] The second floor Dome Room derives from the Pantheon sanctuary, which presents an eight-fold arrangement of recessed niches behind a ring of Corinthian columns and pilasters (**Fig. 6**). But the Dome Room of the Rotunda introduces a ring of twenty coupled Composite columns that support two new galleries for book storage (**Fig. 5** and **Fig. 7**). The basement and first floor levels of the Rotunda depart from the Pantheon completely, presenting a new floor plan composed of three ovoid rooms (**Fig. 8**).

Leoni's Palladio notes that the Pantheon "bears the figure of the World, or is round" [Leoni 1742, II: IV, xx, 28]. In fact, both structures portray the cosmic heavens, as the sun penetrates a central oculus, casting its image around the bowl of the dome (Jefferson installed a skylight for the oculus of the Rotunda, while that of the Pantheon remains unglazed). But Jefferson, wary of esoteric cosmologies, never intended his dome to evoke a temple or mystical symbol. Rather, it was to be an instrument of enlightenment for modern science education. To this end, he imagined the interior fitted mechanically like a planetarium with moveable stars and constellations (Specification Book for University of Virginia, 18 July 1819, 2, N-318 [O'Neal 1960, 52-53, doc. 94; Nichols 1961, 39; Jefferson 1995b]).

GEOMETRIC ANALYSES OF THE LEONI *PALLADIO* PANTHEON

Given the special relationship between Jefferson's Rotunda and the Pantheon studies in Leoni's 1721 *Palladio*, it is useful to examine both designs for evidence of geometric techniques, then compare the results. At first glance, the *Palladio* Pantheon features distinct geometric shapes: a circular dome and plan; an octagonal arrangement of recesses within the sanctuary; an implied square frame about the portico; and triangular pediments (**Fig. 3** and **Fig. 6**). Closer examination suggests the presence of incommensurable ratios inherent in geometric figures: the $1:\sqrt{3}$ ratio in the regular triangle and the ratio $1:\sqrt{2}$ in the square. We begin with the front elevation of the Leoni *Palladio* Pantheon.

The Leoni *Palladio* Pantheon, Elevation: Root-3 Proportions (Fig. 9). A circle traces the exterior surface of the Pantheon dome, in elevation. A new circle of equal radius is drawn from the top of the dome, such that the center of one circle lies on the circumference of the other. The result is a new figure composed of two 120° arcs, or a *vesica piscis*. Its vertical and horizontal axes are in $1:\sqrt{3}$ ratio. Its horizontal axis locates the base of the dome.

A square is drawn about the original circle. In addition, the top of the dome locates one apex of an equilateral triangle. The remaining two apexes touch the right and left sides of the square, while locating the building's baseline. The half-side of the equilateral triangle and its altitude are equal in length to the axes of the *vesica piscis*, in $1:\sqrt{3}$ ratio.

The Leoni *Palladio* Pantheon, Floor Plan: Root-2 Proportions (Fig. 10). A circle traces the outside wall of the Pantheon sanctuary, in plan. Two squares are inscribed within the circle, their apexes dividing the circle in eight equal sections at the sanctuary's recessed niches. A new circle, drawn through the eight points where the squares intersect, locates the inside face of the sanctuary wall.

The radius of the circle tracing the outside wall, and the side of its inscribed square, are in $1:\sqrt{2}$ ratio. The half-side of the inscribed square, and the radius of its circumscribing circle, are in $1/\sqrt{2}:1$, or $1:\sqrt{2}$ ratio. These elements comprise the geometric proportion, $1/\sqrt{2}:1::1:\sqrt{2}$.

GEOMETRIC ANALYSES OF JEFFERSON'S ROTUNDA

The previous studies illustrate how the Pantheon expresses $1:\sqrt{2}$ and $1:\sqrt{3}$ ratios inherent in basic geometric shapes. Let us now compare these techniques with Jefferson's own drawings for the University of Virginia Rotunda. Jefferson produced floor plans and elevations in ink on grid paper at a scale of 1" = 10', with each square on the grid equal to one square foot.

Though not immediately apparent, Jefferson's drawings contain pencil lines, erasures and other "hidden" markings that provide valuable information about the design process. In some instances, Jefferson scored or pricked the paper with guidelines, a common practice in eighteenth-century Virginia. Such lines and arcs, produced with a straightedge, compass or divider, offer insight into Jefferson's methods for laying out building components; markings such as these can be observed on Jefferson's original drawings or in high-resolution electronic images available through Electronic Collections at the University of Virginia Library [Jefferson 1995b].

Scored and pricked lines do not always indicate geometric development. Scoring could be used to facilitate the laying in of window or door openings. Pricking enabled the transfer of key points on a drawing to a fresh sheet of paper underneath [Brownell 1992, 150]. But in some cases, scored lines or circles suggest the setting out of geometric patterns or constructions. Holes slightly larger than pricked points locate centers for the drawing of circles and arcs.

Compared with the Pantheon, which is low and wide, the Rotunda's square-like exterior gives the appearance of greater height. But $1:\sqrt{3}$ and $1:\sqrt{2}$ ratios appear, to similar effect. We begin with the Rotunda's south elevation.

The Jefferson Rotunda, South Elevation: Root-3 Proportions (Fig. 11). As in the Pantheon, a circle traces the exterior surface of the Rotunda dome. In fact, Jefferson draws such a circle, dotted in ink (**Fig. 2**). A new circle of equal radius is drawn from the top of the dome. The result is a *vesica piscis*, with vertical and horizontal axes in $1:\sqrt{3}$ ratio. The horizontal axis locates the base of the dome, which spans 120°. A notation by Jefferson specifies that half the dome's surface spans "60°."[13]

A square is drawn about the circle. Its base locates the baseline of the Rotunda. In addition, the top of the dome locates one apex of an equilateral triangle. The remaining two apexes touch the right and left sides of the square, while locating the floor level of the portico. The half-side of the equilateral triangle and its altitude are equal in length to the axes of the *vesica piscis*, in $1:\sqrt{3}$ ratio.

The Jefferson Rotunda, Dome Room Floor Plan. While the front elevation of the Rotunda adopts the Pantheon's visual appearance and proportions, the interior rooms are designed with more individual expression. Jefferson's Dome Room evokes the Pantheon sanctuary in its open circular plan and dome, and in the placement of a circular colonnade in $1:\sqrt{2}$ proportion to the outer sanctuary wall. But the Pantheon colonnade develops from an octagonal arrangement of recessed niches, while the Rotunda presents twenty pairs of Corinthian columns. The columns are arranged according to a five-fold pattern of symmetry in $1:\phi$ ratio. The ratio of $1:\phi$, or 1: 1.6180339... was known in Jefferson's day as the "extreme and mean" ratio (**Fig. 6** and **Fig. 7**).

Root-2 Proportions (Fig. 12). In plan, the outer sanctuary wall relates to the colonnade through a diminishing series of squares inscribed by circles, drawn *ad quadratum*. In fact, the outside circle lies just inside the outer sanctuary wall, but it coincides precisely with a scored circle that may be detected in Jefferson's drawing. The circles' radii increase in $1/\sqrt{2}:1$, or $1:\sqrt{2}$ ratio.
The radius of the circle tracing the outside wall, and the side of its inscribed square, are in $1:\sqrt{2}$ ratio. The half-side of the inscribed square, and the radius of its circumscribing circle, are in $1/\sqrt{2}:1$, or $1:\sqrt{2}$ ratio. Thus, these elements comprise the geometric proportion, $1/\sqrt{2}:1::1:\sqrt{2}$.

"Extreme and Mean" Proportions (Fig. 13). In addition to the forty coupled columns, as shown, Jefferson's plan drawing reveals a smaller ring of twenty erasure marks. These marks delineate an alternative plan for the Dome Room that features twenty single Corinthian columns [Sherwood and Lasala 1993, 29]. The erasures correspond to points of intersection between four stellar pentagrams, inscribed within the circle of the outer sanctuary wall. The pentagrams follow a pattern of symmetry based on the ratio $1:\phi$. Scored lines suggest that Jefferson used a protractor to divide the circle into twenty equal parts.[14]

GEOMETRIC ANALYSES OF THE JEFFERSON ROTUNDA OVOID ROOMS

While Jefferson's Dome Room borrows the open plan of the Pantheon as a point of departure, the first two floors of ovoid rooms follow different design sources (**Fig. 8**). Each floor plan clusters three ovoid rooms about a central hallway, leaving space for a double stairway in the fourth quadrant. O'Neal notes that the plan evokes a country house in Christian Ludwig Stieglitz's *Plans et dessins*, a collection of neoclassical designs which Jefferson owned and later sold to the Library of Congress [O'Neal 1978, 330-335, pl. CXXVI]. Others believe they suggest the Broken Column House of Le Désert de Retz, the late eighteenth-century private folly garden of François de Monville near Marly, which Jefferson visited and admired in France [Ketcham 1994, 5-8 and 98, fig. 78 (ground floor plan)]. Jefferson's knowledge of architectural sources was extensive. Rather than imitate any one of these designs, he likely adapted their common essence to a new set of requirements.

Jefferson experimented with ovoid forms long before designing the University Rotunda. In 1792, he devised a similar scheme for the Capitol Building in Washington, clustering four oval spaces about a central area. Ovals appear in an early study for a retreat, about 1794, and again in studies for a Rotunda-plan house, probably intended for the President's House in Washington, about 1792 and 1800-1803 [Massachusetts Historical Society, N-388, N-493-495, 529; University of Virginia Library, N-409-410 (referenced in Nichols 1961, 41, 43, 44); Kimball 1968, fig. 33; Jefferson 1995a, N-388, N-409].

Jefferson's scheme for the University Rotunda takes a novel curvilinear approach that appears to utilize the "extreme and mean" ratio with originality and vigor. There is, in this masterwork of proportion, a freedom of expression that reflects the youth and vitality of America's revolutionary spirit, as Jefferson reinvents classical forms through techniques of his own creation.[15]

"Extreme and Mean" Proportions (Fig. 14). A circle traces the inside face of the exterior wall, in plan. The circle's two horizontal radii each divide at their midpoints. Vertical axes are drawn through these midpoints, defining the width of the ovoid room above. The two horizontal radii divide in "extreme and mean" ratio, locating the centers of the ovoid rooms on the right and left. Vertical axes drawn through these points extend through the column centers along the sides of the portico, where scored lines are delineated.

"Extreme and Mean" Proportions (Fig. 15). The overall proportions of the right and left ovoid rooms derive from "extreme and mean" proportions. The hallway opening ($2/\phi^3$), the horizontal opening of each ovoid room ($2/\phi^2$), and the portico opening between the column centers on the ends ($2/\phi$) are in $1:\phi$ ratio. In other words, $2/\phi^3 : 2/\phi^2 :: 2/\phi^2 : 2/\phi$ or $1:\phi$ At the far left edge of the paper, along the horizontal axis, a hole in the paper locates the center of the arc which delineates the left ovoid room.[16]

"Extreme and Mean" Proportions (Fig. 16). The horizontal segment of a pentagram matches the horizontal diameter of the inside face of the exterior wall. Two additional pentagram segments intersect the horizontal diameter at the inside faces of the ovoid walls. The pentagram inscribes a circle that is slightly larger than the inside face of the exterior wall.

"Extreme and Mean" Proportions (Fig. 17). The pentagram and its circumscribing circle are repositioned to show that the circumscribing circle matches the outside face of the exterior wall.

GEOMETRIC PROPORTIONS IN THE WORKS OF THOMAS JEFFERSON

Lacking actual drawings that illustrate specific geometric constructions, it cannot be said definitively that Jefferson utilized incommensurable proportions to design the University Rotunda. Such drawings have not been identified, but among the approximately 70,000 surviving documents connected to Jefferson (the number estimated by Monticello Research Librarian Bryan Craig), few have been analyzed for geometric content. Meanwhile, a comparative analysis between Palladio's renderings of the Pantheon and Jefferson's plans suggests that both designs developed from similar geometric techniques.[17]

But was Jefferson knowledgeable of such techniques and was he inclined to use them? Jefferson's special familiarity with the tools of geometry dates to his early childhood, when his father Peter used such instruments as a surveyor and explorer, then bequeathed them to his son upon his death [Hellenbrand 1990, 21-22]. It was Jefferson's practice to keep a building notebook with various mathematical calculations, including solutions to problems in practical geometry. Although he drafted his designs on graph paper, the plans do not generally conform to the whole number increments of the grid. Where he resorts to complex fractions, they are sometimes calculated to five or more decimal places [McLaughlin 1988, 82]. Furthermore, Jefferson drafted his plans with a drawing compass and ruling pen, sometimes scoring the paper with lines and arcs that served as geometric guidelines.

Such practices support the theory that he applied incommensurable proportions, which he generated by drawing geometric figures. One could argue that Jefferson employed the common practice of substituting incommensurable measures with more workable whole number estimates, without the aid of geometric constructions. But given his mathematical orientation and his belief that one must draw geometric figures to understand them, it is likely he at least conceived such measures in geometric constructs. At any rate, he commonly used geometric techniques, or at least a protractor, to produce polygonal shapes for buildings.

Jefferson left scant evidence of applying incommensurable proportions through geometric techniques, but the evidence is compelling. One example is the Washington Capitol, where he specified that the properties of neighboring landholders "be sold out in breadths of fifty feet; their depths to extend to the diagonal of the square" ("Opinion on Capitol," 29 November 1790 [Ford 1904-1905, VI: 49]). In other words, such lots were to conform to the incommensurable ratio of $1:\sqrt{2}$.

There is also evidence that Jefferson's octagonal villa at Poplar Forest, begun in 1806, developed from geometric figures. A page of his own notes and scribbles, presumed to date to the project, includes a rather sophisticated geometric construction for drawing three sides of a small octagon and two sides of a larger octagon, both accomplished by dividing two sides of a square in $1:\sqrt{2}$ ratio (a drawing of two completed octagons and an algebraic proof accompany the construction) [Chambers 1993, 21 and 22, fig. 14]. The similarity between his geometric construction and his conceptual plan for Poplar Forest, intended until 1804 for his farm of Pantops, is evident.[18]

This geometric construction appears again during various phases of building and remodeling at Monticello. Jefferson's building notebook for Monticello contains a theorem for drawing "three sides of an octagon" on a given base, dated 1771(?), apparently in preparation for octagonal projections in the accepted plan [Kimball 1968, figs. 24, 94; Nichols 1961, 34, N-123]. A similar construction, dated 1794-1795(?), accompanies his studies for the remodeling of Monticello [Kimball 1968, fig. 140; Nichols 1961, 34, N-138].

Having developed such geometric techniques at Poplar Forest and Monticello, it is possible that Jefferson employed a similar process for the University of Virginia. His drawing for the south elevation of the Rotunda reveals a dotted circle that traces the sphere of the dome and is tangent to the outside walls and basement floor of the building (see **Fig. 2**). In addition, a letter to John Neilson, the former master carpenter and joiner at Monticello contracted to build the Rotunda, specifies a similar relationship on the building's north face where "the lower edge of the Architrave fills in the same line as the center of the Sphere..." (5 May 1823 [O'Neal 1960, 26, doc. 17; Jefferson 1992]).

Evidence that Jefferson developed more complex geometric relationships may lie embedded in the plans. We have seen how his dotted circle, which traces the dome in the Rotunda's south elevation, forms the basis of geometric constructions that locate key elements of the building facade. Similar geometric techniques may be observed in the Dome Room and First Floor plans.

MATHEMATICAL AND ARCHITECTURAL TREATISES KNOWN TO JEFFERSON

Jefferson was not the sole architect or builder to utilize geometric techniques in Colonial times. There is evidence that some domestic buildings in eighteenth-century Virginia were laid out geometrically. Marcus Whiffen believes such techniques date to medieval building practice, and has identified the root-2 rectangle in the Archibald Blair and George Wythe houses in Williamsburg. The equilateral triangle appears in the Blair and Wythe elevations, as well as Westover in Charles City County, and the President's House at the College of William and Mary [Whiffen 1984, 83-88].[19]

Whiffen's analyses of public buildings in Colonial Williamsburg are also noteworthy. The Bruton Parish Church, 1711-15, a cruciform church designed by Virginia Governor Alexander Spotswold, reveals a pattern of equilateral triangles and $1:\sqrt{3}$ proportions, in both plan and elevation. Williamsburg's octagonal Magazine in Market Square, likely designed by Spotswold, unfolds from the $1:\sqrt{2}$ relationship between the side and diagonal of a square [Wiffen 1958, 80-81, 85-87].[20]

Most likely, Jefferson was acquainted with geometric techniques and constructions from books, which he owned or recommended to others.[21] Among these are architectural and mathematical treatises, both classical and contemporary, containing instructions for achieving incommensurable proportions.

Palladio, in particular, was a major influence for Jefferson and other philosophers and building practitioners in his day [O'Neal 1978, 2]. Jefferson, who is reported to have said that Palladio "was the bible" (Colonel Isaac A. Coles to General John Cocke, 23 February 1816 [Adams 1976, 283]) preferred Palladio's buildings even to those in the French Louis XVI style, although he knew them only through books.[22] Jefferson owned numerous editions of Palladio throughout his life. At least three were produced with plates redrawn by Giacomo Leoni, whose 1721 edition served as Jefferson's primary source for the University Rotunda and as a pattern book for buildings throughout the campus [O'Neal 1960, 2; O'Neal 1978, 255].

Beside Palladio, Jefferson could have studied techniques of geometric proportion in Vitruvius's *De architectura*, Alberti's *De re aedificatoria* and Serlio's *Architettura*. Serlio's *Architectura* was well known to those gentry of Colonial Virginia who were architectural patrons, if not designers themselves [Brownell 1992, 138]. Jefferson owned only the posthumous 1575 edition of Serlio's Book VII, with parallel texts in Latin and Italian, but it is likely he knew the entire series, including the contents of Book I, a compendium on geometry.

Geometric techniques that appear in Palladio's Pantheon and Jefferson's Rotunda may be found in these sources [Serlio 1996: I, 10 (fol. 5); 29 (fol. 20); Alberti 1988: VII, iv, 196]. Serlio, Alberti and others produce regular polygons through $1:\sqrt{2}$, $1:\sqrt{3}$, and "extreme and mean" geometric constructions. Vitruvius reports that ancient Greek and Roman theatres derived from patterns of squares and triangles and their inherent root-2 and root-3 proportions. Specifically, he states that Roman theatres emerged from a twelve-fold arrangement composed of four triangles, while the theatres of Greece followed a twelve-fold arrangement composed of three squares. This geometry is inscribed within the *orchestra* circle, but locates key elements of the auditorium and stage buildings [Vitruvius 1999: V, vi, 68-69; V, vii, 70].[23] Serlio demonstrates a diminishing series of squares inscribed by circles, drawn *ad quadratum* [1996: I, 9 (fol. 3)]. Elsewhere, he transforms a square into a regular octagon, by swinging arcs from each of the square's four corners [1996: I, 28 (fol. 19)]; each arc is equal in radius to one-half the diagonal of the square. This method, which results in subdividing the original square into one center square, four smaller corner squares, and four $1:\sqrt{2}$ rectangles, is also called the Sacred Cut [Brunés 1967, 54-108].

Serlio's study for the door of a church, which he draws within a square, does not relate specifically to Jefferson's Rotunda or to the Pantheon, but is noteworthy. The diagonal of the square (root-2 to a side of 1) crosses the diagonal of half the square ((root-5)/2), locating the height and width of the door's opening. The opening that results is a double square with a ratio of width to height as 1:2. The width of the door is in ratio to the side of the square as 1:3. The height of the door is in ratio to the side of the square as 2:3. Thus, Serlio arrives at the finite ratios of musical consonance by crossing diagonals that express incommensurable measures associated with geometric figures [1996: I, 32-33 (fol. 23)]. The intent of this construction has been much debated. Wittkower acknowledges that the diagonals are incommensurable in value, but believes this to be a minor consequence of the whole number system of proportion [1988, 126-127]. However, Orrell notes that Serlio would not have devoted his First Book to geometric constructions, unless he recognized their use in setting out proportions in building plans [1988, 146].

Beside these classical treatises, Jefferson's architectural library contained numerous contemporary texts, including pattern-books of plan and elevation designs, and builder's handbooks on technical and practical matters. A significant number contain guides to geometric proportioning, including works by English authors Robert Morris, James Gibbs, Batty Langley and Peter Nicholson, as well as the French engraver Sébastien Le Clerc [O'Neal 1978, 136-37, 140, 186-87, 189, 191, 193, 231, 236-37, 240, 242-47; Sowerby 1952, IV: 23].

Morris's *Select Architecture* [1973] furnished numerous models and patterns for Jefferson's designs, and likely inspired his polygonal interiors and projections. A collection of fifty plans and elevations for town and country situations, it advocates arithmetical and harmonic proportioning in building design. The plans themselves feature circles, squares and octagons, with a significant number of rooms drawn in $1:\sqrt{2}$ proportion [Lancaster 1951, 4; Morris 1973, pls. 11, 17].

Widely known in rural England and the Colonies, Gibbs's *Rules for Drawing the Several Parts of Architecture* and *A Book of Architecture* were among Jefferson's earliest owned titles. A popular and accessible source for Palladian design, *A Book of Architecture* contains Gibbs's drawings and designs for churches, houses, collegiate buildings and various architectural details. *Rules for Drawing* offers a simplified method for drawing the orders that avoids fractions, as well as techniques for drawing classical and Georgian rooms, mantles and doors [O'Neal 1978, 136-37, 140; Brownell 1992, 42, 140]. Sometimes, "geometrical rules" are provided, as when a *vesica piscis* describes the opening of a window that is proportioned to a square and a half [Gibbs 1732, 20 and pl. XLV].

Rules for Drawing may have been a source for Jefferson's octagonal designs for Poplar Forest and Monticello, for it contains a geometrical construction for obtaining two sides of an octagon. The same technique produces the angles for triangular pediments in Gibbs's design for an arched door in the Doric order [1732, 29 and pl. XXXVII, no. 2]. It is certain that Jefferson knew the drawing, for he referenced it in designs for exterior parlor doors in his building notebook for Monticello, about 1770 [Kimball 1968, figs. 20, 72].[24]

Langley's *Practical Geometry* [1726] offers techniques for applying Euclidean geometric constructions to surveying and to building and garden design. Numerous exercises yield incommensurable ratios, among them: a diminishing series of circles and squares drawn *ad quadratum*; a method for inscribing a circle within an equilateral triangle; a technique for dividing a line in "extreme and mean" ratio; and a method for producing the spiraling shaft of a Doric column, drawn *ad quadratum*. A single figure produces the triangle, square, pentagon, hexagon, octagon, and other geometric figures through root-2, root-3, and *phi* constructions, all inscribed within a circle with a radius of 1. It is interesting to note that Langley calculates incommensurable values to four decimal places, instead of approximating them in simple whole number integers, as was often the convention. The ratio $1:\sqrt{2}$, or .7071 : 1, is expressed $7,^{0710}$ to $10,^{0000}$. The "extreme and mean" ratio, or .61803 : 1, is $6,^{1803}$ to $10,^{0000}$ [1726, 11 and pl. 1, fig. XXX; 17 and pl. 1, figs. XLII, XLIII; 39 and pl. IV, fig. XV; 66 and pl. VII, fig. V; 41,42].

Nicholson's *Principles of Architecture* begins with a section on Practical Geometry and offers constructions for regular polygons, including a method for drawing a pentagon based on the "extreme and mean" ratio. A square transforms into regular octagon by swinging arcs equal in radius to one-half the diagonal of the square [1809, 13-14 and pls. 12-13]. These and other constructions may be viewed in Nicholson's *Carpenter's New Guide* [1793, pl. 6, fig. 8 and pl. 31, fig. D].

In addition to these English titles, Jefferson owned Le Clerc's *Traité de Géometrié*, a handbook of advanced geometric constructions for artisans, as well as Le Clerc's *Treatise of Architecture*. Jefferson cites *Traité de Géometrié* as the source for his own sketch of an octagon "one side of which only is given" [Jefferson, *Original Jefferson Letters*, Edgehill Randolf papers #5333]. Jefferson did not own Le Clerc's *Practical Geometry,* an elementary guide containing numerous constructions that are relevant to this paper's geometric analysis. These include: drawing a square circumscribed about a circle; dividing a given line in "extreme and mean" proportion; and constructing a pentagon by deriving the "extreme and mean" ratio [Le Clerc 1744, 62-63 and pl. 2, fig. 20; Le Clerc 1742, 113, 146-7, 180-1]. Likely, Jefferson was well acquainted with such techniques and did not require Le Clerc's text as a reference.

Today it is commonly accepted that $1:\sqrt{2}$ and $1:\sqrt{3}$ ratios were applied to architecture since Roman times, if not before. But the use of "extreme and mean" ratios is not without its detractors. Lionel March and others argue that the proportion was known mathematically and philosophically, but was not applied architecturally as "a key to aesthetic measure" until the nineteenth and twentieth centuries, when it became known as the Golden Section [March 2001, 85-86; Frings 2002].

But from Euclid through the Renaissance and beyond, the "extreme and mean" ratio was not unknown [Fletcher 2001, 110-111]. Euclid provides a construction for dividing a line into "extreme and mean ratio," such that the short segment is in ratio to the longer as the longer is in ratio to the whole (or $1:\phi$) [1956, II: 267 (bk. VI, prop. 30); II: 188 (bk. VI, def. 3)]. Euclid's Book XIII explains how to inscribe the five regular Platonic solids within a sphere. Of the five, the icosahedron and the dodecahedron involve the pentagon and its inherent "extreme and mean" proportions [1956, III: 453 (bk. XIII, prop. 8)]. As early as 1726, mathematicians, builders and architects published exact geometric constructions based on the $1:\phi$ ratio. Nicholson, Langley, Le Clerc and others illustrated its use for architects and builders, demonstrating numerous constructions in elementary texts. The English encyclopedist Ephriam Chambers linked the "extreme and mean" ratio to the pentagon's exact construction, and, in addition, provided the appropriate algebraic proof. [Chambers 1728, I: 141, fig. 64; Sowerby 1952, V: 152; Le Clerc 1742, 112-3, 180-1; Langley 1726, 11 and pl. 1, fig. XXX; Nicholson 1809, 14 and pl. 13]. As has been noted, Jefferson owned each of these sources at some time during his life.

CONCLUSION: HARMONY OUT OF DIVERSITY

Works such as the University of Virginia permitted Jefferson to reinvent timeless architectural forms and to express universal aspirations for freedom and equality within a distinctly American context. As a statesman, he envisioned a unified nation capable of embracing a vast array of religious, social and political beliefs. His architecture offered a complimentary vision of unity, crafting the beauty of *concinnitas* from a rich variety of material elements.

One can imagine how Jefferson's passion to reconcile individual differences found its way into his designs through an imaginative use of mathematical proportion. But diverse harmony is evident in non-mathematical ways as well. One example is the subtle asymmetry of the University of Virginia Lawn, where the campus is organized about a central north-south axis. To accommodate the slope of the site, the gardens are deeper on the east than on the west. At first, Jefferson conceived a balanced plan on either side of the Lawn's central axis, but for practical reasons, he agreed to extend the eastern range of hotels and dormitories by approximately seventeen feet, deepening the gardens behind the eastern pavilions [Wilson 1993, 39]. Yet the spirit of proportion prevails. In similar fashion, the Lawn's Tuscan colonnade expresses an overall order and repetition of elements, even as individual pavilions present different facades.

Nonmathematical expressions of proportion are evident throughout the campus Lawn. The ten pavilions comprise a complex unity of irregularly spaced columns of different orders and sizes. As one approaches the Rotunda, there is a decrease both in the distance between each pavilion and in the height of the railings above the colonnades. Such graduated changes, motivated possibly by site constraints and the need for more pavilions, create the illusion of greater depth and distance [Nichols 1976, 180; Wilson 1993, 71 and 90, n. 108]. Diversity is everywhere to be seen, as Lewis Mumford notes, "now with a flat, now with a gabled roof, now with small, superimposed columns for the front porches, now with a full-scale temple portico, the austere ancient pattern sometimes broken in the balconies by a diamond pattern or a Chinese fret-all these variations on the central theme are music for the eye"

[Mumford 1941, 72].

Jefferson's designs succeed largely because unique, individual elements are conceived as parts of a whole. The University campus offers a total ensemble of spaces for living, learning and socializing, and for privacy and discussion. It is likely that Jefferson envisioned a learning environment such as he enjoyed with George Wythe and William Small at William and Mary, where mentors and students shared everyday experiences and explored ideas in a democratic fashion [Wenger 1995, 369]. The landscape comes into focus through a variety of visual experiences, with the Rotunda dominating the north end of the campus, a mountain view commanding the south, and the Lawn drawing attention to the center.

The total coordinated effect reflects a special sensitivity to harmony and proportion, and an ability to produce a rich and vibrant unity from a vast array of particulars. Mumford notes that "the beauty of the University of Virginia buildings that Jefferson designed does not lie in any single detail; it does not lie in any single building; it does not even lie in any single row: it derives from the order and purpose that underlies the whole and creates a harmony, practical and aesthetic, between its various parts" [1941, 75].

A sense of harmony is evident even in Jefferson's methodology and in his practice of designing collaboratively. Jefferson admired Palladio greatly, but drew from an array of historical sources. He freely sought and openly acknowledged the contributions of others, designing the university in concert with fellow members of the Board of Visitors, architects such as Dr. William Thornton and Benjamin Henry Latrobe, master builders and craftsmen such as John Neilson and James Dinsmore, and others. Men of both white and black races contributed to the building of the University Campus.[25]

Jefferson believed that knowledge was constantly improving and that society ought to continually reinvent itself and its principles. "Can one generation bind another, and all others, in succession forever?" he wrote in 1824. "I think not. The Creator has made the earth for the living, not the dead." Jefferson respected the lessons and traditions of history, but believed that nothing is "unchangeable but the inherent and unalienable rights of man" (Jefferson to Major John Cartwright, 5 June 1824 [Peterson 1984, 1493-1494]). The terrors and tyrannies of English history prompted Jefferson to advocate individual rights, which he believed were granted by authority of natural law. He supported, in theory, the right of succeeding generations to repeal laws and constitutions, for it was the duty of each new generation to improve on the past and to determine its own destiny (Jefferson to James Madison, 6 September 1789 and Jefferson to John Wayles Eppes, 24 June 1813 [Peterson 1984, 963, 1280]).

In this spirit, he designed the University campus by looking to architectural sources in the past, not to duplicate or reconstruct them, but to build upon their principles and to adapt them to the spirit and requirements of his day. In Jefferson's hands, the classical canon produced a rigorous architecture of vital and individual expression.

This spirit of reinvention is evident in Jefferson's architecture as he adapts the classical style to suit his time and locale, taking rules from the past and making them his own. To produce the University of Virginia, he transformed the classical Greek temple and Roman villa into an "academical village" of hotels and pavilions, hoping that students and teachers of the new republic might convene in the free exchange and pursuit of knowledge. Rather than duplicate the Roman Pantheon to create the University Rotunda, he modified notable elements of the original facade, then reconfigured the interior to serve a specific academic program.

By reducing the Pantheon's monumental scale, Jefferson gave the Rotunda a distinctly American expression. The building is constructed of locally fired common red brick to express the nation's new democratic character. Native materials are used throughout, including timber and rock obtained from a nearby tract of land that Jefferson purchased [Lasala 1992, 20].

But the fusion of classical techniques with individual expression is perhaps most evident in Jefferson's use of mathematical proportions. We have noted that the front elevation of the Rotunda follows $1:\sqrt{3}$ proportional techniques similar to those apparent in the Pantheon, but these are modified to support a more egalitarian scale. The upper Library plan evokes the Pantheon sanctuary in the $1:\sqrt{2}$ relationship of its colonnade to the outer sanctuary wall. But the Library's ring of twenty coupled columns introduces a new symmetrical pattern of four interlaced pentagons. Meanwhile, Jefferson's scheme of oval rooms on the first and second floors departs from the Pantheon dramatically, employing the "extreme and mean" ratio in a new composition.

As Richard Guy Wilson remarks, "Jefferson belonged to his time: classicism was the language of architecture, but it was elastic" [1993, 70]. Jefferson's great contribution to the classical tradition was the notion that timeless principles are enhanced by the discoveries of later ages, and require perpetual reinvention.

Today, the University Lawn remains a hallmark of American architecture and a testament to its maker's hope for a new nation. The buildings continue to serve as they did in Jefferson's day, an "academical village" with professors and some one hundred students still living and learning in dormitories and pavilions along covered walkways; the buildings have remained in continuous use since their completion as a group in 1826 [*World Heritage List Nomination* 1987, 4a]. If Jefferson did employ geometric techniques to help synchronize the campus' vast array of design elements, as this paper proposes, they echoed a call for unity in the art of building, no less than the art of life.

Classical theories of proportion have fostered unity and harmony since ancient times, reflecting the ethical imperative to serve that which is greater than our individual selves. More than mere devices for producing beauty, proportional techniques speak to the special interdependence of individual and collective values that Jefferson deemed essential for a just and well-regulated society. Jefferson's First Inaugural Address charged the nation to "unite in common efforts for the common good...that though the will of the majority is in all cases to prevail...that the minority possess their equal rights.... Let us restore to social intercourse that harmony and affection without which liberty and even life itself are but dreary things" [Peterson 1984, 492-493]. The rich and diverse architectural unity of the University of Virginia, achieved through geometric proportions and other vocabularies, invokes this eternal theme with renewed vigor, endowing timeless architectural principles with a specific American expression.

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NOTES
[1] It has long been conjectured that Latrobe played a more pivotal role in the design of the Rotunda and the Lawn's other buildings. This theory is based on a letter and sketch by Latrobe, dated 24 July 1817 [Jefferson 2000], and a subsequent set of drawings, which are now missing [Kimball 1968, 75-82; Riddick 1988, 14-22, 38; Sherwood and Lasala 1993, 16-21, 35; Woods 1985, 272, 280-281]. return to text

[2] Jefferson's early plans show a 200' wide strip of land divided into three flat terraces of 255' each in length. See Specification Book for University of Virginia, 18 July 1819, 3, N-318 [Nichols 1961, 39; Jefferson 1995b]. "The site is lately bought and on a survey it is on a narrow ridge, declining North to South, so as to give us a width between the 2. rows of pavilions of 200 f. only from East to West, and the gentle declivity of the ridge gives us three levels of 255. f. each from N. to South, each about 3. feet lower than the one next above...." (Jefferson to Benjamin Latrobe, 3 August 1817 [Kimball 1968, 190]). return to text

[3] See Jefferson, "An Account of the Capitol in Virginia," n.d., *Miscellaneous Papers* [Lipscomb and Bergh 1905-06, XVII: 353]. Jefferson's primary source for the Rotunda was the 1721 Leoni edition of Palladio's *I quattro libri*, which claimed that the Pantheon "was erected in the time of the *Republick* [sic]" [Leoni 1742, II: IV, xx, 28]. return to text

[4] "It was my great good fortune, and what probably fixed the destinies of my life that Dr. Wm. Small of Scotland was then professor of Mathematics…. He, most happily for me, became soon attached to me & made me his daily companion…." (Jefferson, *Autobiography*, 6 January 1821 [Peterson 1984, 4]). At William and Mary, Small taught a diverse curriculum of physics, metaphysics, philosophy, mathematics and natural philosophy. He replaced the convention of rote memorization with a lecture style of teaching in which he frequently subjected physical phenomena to scientific observation and analysis [Bedini 1990, 25-26]. return to text

[5] Jefferson to William Duane, 1 October 1812 [Ford 1904-05, XI: 267-268]. Jefferson spent his early youth in the Latin school of Reverend William Douglas, where he probably studied bookkeeping, algebra, geometry, measuring, surveying, mechanics, navigation and geography, in addition to French, Latin, Greek and English. Later, he studied at the school maintained by Reverend James Maury. Maury provided instruction in Greek and Latin and encouraged Jefferson's curiosity about the natural world [Bedini

1990, 12-16]. At seventeen, Jefferson entered the College of William and Mary in Williamsburg, Virginia, intending to continue his studies in Greek and Latin "& likewise learn something of the Mathematics" (Jefferson to John Harvie, 14 January 1760 [Jefferson 1992]). return to text

[6] Architectural schools did not exist in America during Jefferson's youth, but Jefferson owned the most extensive eighteenth- and early nineteenth-century architectural library now known [(Hafertepe and O'Gorman 2001, xviii]. He assembled at least two substantial libraries during his lifetime, but unfortunately neither collection is now available for first-hand examination. The first and larger of the two was sold in 1815 to form the Library of Congress, replacing books burned by the British during the War of 1812; most of this collection was destroyed by fire in 1851. Jefferson bequeathed his second library to the University of Virginia, but the books were dispersed, having been sold in 1829 to settle his estate [Kimball 1968, 90-93]. return to text

[7] Jefferson designed the Virginia Capitol with the assistance of French architect and antiquarian Charles-Louis Clérisseau. "The Capitol in the city of Richmond, in Virginia, is the model of the Temples of Erectheus at Athens, of Balbec, and of the Maison quarree of Nismes [sic]. All of which are nearly of the same form and proportions, and are considered as the most perfect examples of cubic architecture, as the Pantheon of Rome is of the spherical...." (Jefferson, "An Account of the Capitol in Virginia, " n.d., *Miscellaneous Papers* [Lipscomb and Bergh 1905-06, XVII: 353]). The Virginia State Capitol was the first government building designed for a modern republic, the first American work in the classic style, and the first modern public building in the world to adapt the classical temple form on its exterior [Nichols 1976, 169-170; Kimball 1968, 42]. return to text

[8] In 1791, Jefferson sought Piranesi's drawings of the Pantheon to use as sources for public buildings at Georgetown. He acquired the 1779 Jombert edition of Desgodetz' *Edifices antiques de Rome* to produce studies for the Capitol Building in Washington. Desgodetz, known for the accuracy of his measurements, included more than twenty-three detailed studies of the Pantheon in *Edifices*. Jefferson no longer owned a copy of Desgodetz when the university was built. He consulted instead the 1721 Leoni edition of *Palladio* and Fréart de Chambray's 1766 *Parallèle de l'Architecture Antique et Moderne* [O'Neal 1978, 91, 118-119, 132, 255, 265; O'Neal 1960, 2; Brownell 1992, 218; Sowerby 1952, IV: 371; Nichols 1976, 169-170]. return to text

[9] See [Lasala 1992], which is based on Jefferson's design drawings and accompanying written specifications. Malcolm Bell has lectured about the influence of the Vitruvian orders on the design of Jefferson's pavilions (University of Virginia, September 2001). Wengel notes that Jefferson did not strictly adhere to classical rules, but modified them to satisfy other requirements. One example is Jefferson's Virginia State Capitol in Richmond, an adaptation of the Maison Carrée measured by Palladio and M. Clérissault [Wenger 1995, 368; Kimball 1968, 142-148]. return to text

[10] Jefferson's first produced architectural designs for his home in the Virginia Piedmont, on a hilltop that he called Monticello, land inherited from his father Peter Jefferson. Between 1784 and 1809, he designed, built, and then remodeled his Monticello residence. Poplar Forest was begun in 1806 and built about eighty miles southwest of Monticello in Bedford County, on land inherited through his wife, Martha Wayles Skelton, upon the death in 1773 of her father John Wayles. return to text

[11] The earliest prints of the University Ground Plan were commissioned in 1821 and named for New York engraver Peter Maverick. Different versions of the Maverick engravings appeared over the years, including a revised plan in 1825 [Sherwood and Lasala 1993, 39-40; Wilson 1993, 48]. return to text

[12] In 1895, the Rotunda was severely damaged by fire, leaving an empty brick shell. Architect Stanford White of New York's

McKim, Mead & White restored the exterior and reconfigured the interior, at the same time that he created an entirely new building that closed off the south end of the Lawn. White replaced the Rotunda's three-story interior with a two-story high Dome Room over a single floor, believing the new design to be more faithful to the Pantheon of Rome and better suited to a University library. The new Rotunda opened in 1898 and contained the University's books until 1938. In 1976, to commemorate the Bicentennial of the Declaration of Independence, the Rotunda was rebuilt to Jefferson's specifications. The interior was restored to its original condition and the Dome Room returned to its original height [Wilson 1993, 55-65]. return to text

[13] In addition, Jefferson's notes for Peter Maverick's 1825 engraving of the University specify that the Rotunda is "crowned by a Dome 120 deg. of the sphere" (3 March 1825 [O'Neal 1960, 1]). return to text

[14] Jefferson produced a homemade paper pattern for a protractor, which may be viewed at the University of Virginia Library. See [Nichols 1961, 43, N-505]. return to text

[15] "Extreme and mean" ratios appear in Jefferson's plans for the Washington Capitol and in the Rotunda. Such ratios, however, are not immediately apparent in the Stieglitz plan and the Broken Column House (compare Figs. 14-17 with an early nineteenth-century floor plan of the Broken Column House). (Boullay, in J. C. Krafft, *Recueil des plus jolies maisons de Paris et de France* (Paris: d'Angleterre et d'Allemagne, Paris, 1808-1810), reproduced in [Ketcham 1994: 39, fig.17]. Also, pl. XIII, *Plans et dessins tirés de la belle architecture* (Leipzig, 1800), reproduced in [O'Neal 1978, 332, pl. CXXVI].) return to text

[16] The author notes that the geometric constructions in Figures 14 and 15 do not match Jefferson's drawing exactly, and believes the slight discrepancy to be the result of paper shrinkage and expansion, which have occurred over time. This is supported by the fact that a circle drawn by Jefferson no longer matches a comparable circle, drawn with a compass today. return to text

[17] Susan Riddick notes that none of Jefferson's drawings match the Rotunda as it was built in 1822-1826 [1988, 30]. Nor do they match the Rotunda that was rebuilt in 1976 to Jefferson's specifications, after Stanford White's interior reconfiguration in 1898. Nevertheless, Jefferson's drawings best express his original conception, even if they do not represent the final word. It is noteworthy that Jefferson's First Floor plan is a work in progress that reveals multiple attempts to produce the desired ovoid form. return to text

[18] Jefferson first proposed the octagonal house for his Pantops farm north of Monticello, as a future residence for his grandson Francis Eppes, but instead used the plan at Poplar Forest, where Eppes eventually settled (Jefferson to John Wayles Eppes, 30 June 1820 [Jefferson 1992]). Compare Jefferson's plan for the house at Pantops, before 1804, and a plan of the house at Poplar Forest (1820?), drawn by John Neilson [Kimball 1968, figs. 193,194; Nichols 1961, 39-40, N-350; Jefferson 1995b, N350]. return to text

[19] Whiffen concedes that the circle may be the guiding geometric factor in the George Wythe House. return to text

[20] Whiffen's calculations are based on whole number measures in feet and inches, but remain within 2% of the true values of root-2 and root-3. return to text

[21] For a complete list of architectural books which Jefferson either owned or recommended for the University Library, see [O'Neal 1978]. return to text

[22] Jefferson made an agricultural tour of southern France and northern Italy in 1787, intending to visit Palladio's home, Vicenza, at a

later time [Nichols 1976, 163, 167]. return to text

[23] Orrell admits that Vitruvius did not expand upon the incommensurable ratios inherent in these plans, but notes that Renaissance interpreters such as Palladio located various playhouse elements according to $1:\sqrt{2}$ and $1:\sqrt{3}$ proportions [1988, 132-133, 140-141]. return to text

[24] See also [Nichols 1961, 33, 34, N-42, N-101; Jefferson 1995a, N-42]. This well-known construction also appears in: [Le Clerc 1724, 150; Chambers 1728, I: 141 and fig. 8; Langley 1726, 11 and pl. I, fig. XXX; *Builder's Dictionary* 1981, I: pl. 4], all owned by Jefferson. return to text

[25] Grizzard [1996] cites the "important but largely undocumented role played by slaves and free blacks." return to text

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