Kim Williams

Spirals and Rosettes in Architectural Ornament

Well-noted in nature for both its frequent appearance and its many variations, the spiral has inspired architectural forms for many centuries. The logarithmic spiral was adapted by the Greeks for the Ionic volute; many generations of architects developed geometrical constructions to approximate the curves of the spiral. A development on the theme of the spiral is the fan pattern, in which spiral segments are translated about the center of a circle. The superimposition of opposing fan patterns results in the rosette. The easily-constructed circular rosette is an ancient and beautiful pavement pattern, and can be varied to lay the base for many other motives.

Introduction

The occurrence of spirals in our natural environment has been by now so well examined and catalogued as to be familiar to most of us. Spiral patterns of growth in the animal world are found in the nautilus shell, the snail's shell, and in the ram's horn; in the plant world we may find them in the sunflower, the pine cone and the pineapple. Natural spirals may be as large as spiral nebulae or as tiny as the spiral structure of the cochlea in the human ear (Figure 1).[1] For centuries architects have incorporated spiral patterns from nature, as well as patterns inspired by spirals if not actually constructed from them, into the built environment. This paper will discuss how the spiral has been used to express concepts of structure and space in architecture.

The Ionic Volute

Greek architects devised three orders of architecture, Doric, Ionic, and Corinthian; Roman architects adopted the Greek orders and produced two of their own, the Tuscan and Composite. An "order" of architecture is defined by the style of the columns used and the details which accompany the columns. The archetype of the logarithmic spiral in architectural decoration is perhaps found in the volute of the capital belonging to the Ionic order of Greek architecture (Figure 2).[2]

One school of thought about the origins of the orders of architecture holds that the individual elements of the order were designed not only to perform a structural function but also in some way to express that function. Consider for a moment the column as a load-bearing element. The shape of the column is expressive of its being placed in compression by the weight which it is to transfer to the base: instead of being a uniform cylinder, the diameter increases towards the lower half of the column, producing a slight deformation known as

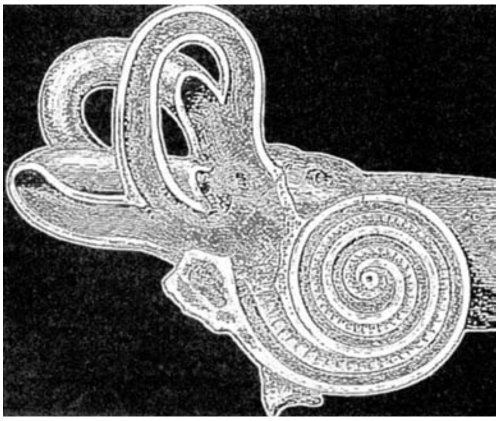

Figure 1.
The spiral structure of the cochlea of the internal ear, which contains the auditory nerve endings.

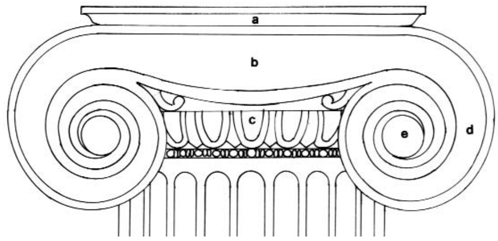

Figure 2.
The Ionic capital and its components: a) abacus; b) cushion; c) echinus; d) volute; e)eye.

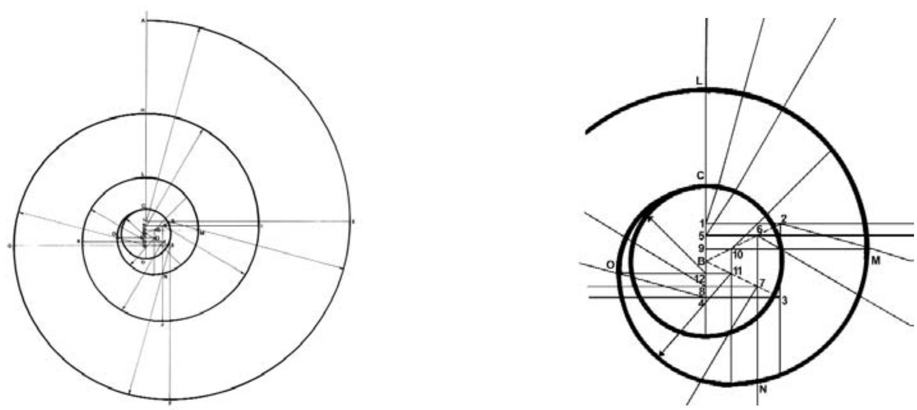

Figure 3.
The volute construction, after Goldman. The construction of the volute is based upon a chosen module, which is related to the diameter of the column. The construction is prepared as follows: draw a vertical line AB equal to 1/2 module. With B as the center, draw a circle with a diameter of 1/9 module: this is the eye of the volute. Divide the vertical diameter of the eye into 4 equal parts (C1, 1B, B4, 4D.) Further subdivide 1B and B4 into thirds (1-5, 5-9, 9-B, B-12, 12-8, 8-4.) Construct squares on 1-4, 5-8, and 9-12. To construct the actual spiral of the volute, the apexes 1 through 12 of the three squares are used in their numerical order as the centers for the arcs which form the volute.. The first arc, with its center at A and a radius equal to 1-A is struck from A to E; the second, its center at 2 and its radius equal to 2-F is struck from E to F. One proceeds in like manner through all remaining centers. The last arc, with center at 12 and a radius equal to 12-O, closes upon the eye at C.

entasis. The volute of the Ionic capital may express compressive force in a similar way: in this case, the element below the abacus is forced into a downward curve. The reader may be familiar with the lotus capitals of Egyptian architecture. To visualize the genesis of the volute, it may help to imagine the result of compression on the lotus bud, that is, that its petals are forced to curl downward under the weight of the load it must bear.

It is to a Roman architect and theoretician that we owe the first description of the Ionic volute and its construction, found in the *Ten Books on Architecture* by Vitruvius. Because of the lack of illustrations, Vitruvius' description is difficult to interpret, and after the rediscovery of the classical orders in the Renaissance, various formulae for constructing the volute, all purported to be based upon that of their Roman predecessor, were published. Without citing an exhaustive list all who championed various methods, some of the most important include Leon Battista Alberti in the 15th century, Andrea Palladio, Sebastiano Serlio and Giacomo Vignola in the 16th century, and William Chambers and James Gibbs in the 18th century. The method which I have chosen to present for the purposes of this study is that presented in Bannister Fletcher's authoritative survey of historic architecture (Figure 3). This method concentrates on the construction of the logarithmic spiral which forms the volute. In a second step, to the first spiral of the volute it is added a second which forms the fillet, or thickness, of the volute.[3]

The procedure involves establishing a module for the construction, which is related to the diameter of the column. The dimension of the eye of the volute is determined in proportion to the module. The method discussed here establishes the eye as 1/9 of the module, or 3-1/3 parts of a module which has 30 parts. Vertical line A-B equal to 1/2 module is drawn. The construction proceeds by drawing the eye concentric with the center of the module (point B in Figure 3). The diameter of the eye is divided into 4 equal lengths (C-1, 1-B, B-4, and 4-D); 1-B and B-4 are divided into thirds. Three squares are constructed with sides 1-4, 5-8, and 9-12 respectively. Beginning with the compass point at 1 and a radius equal to 1-A, an arc is drawn to point E. At E the compass point is moved to point 2, and an arc of radius 2-E is drawn to point F. The construction continues in this manner, changing compass location and radius at each 90 junction, until at last, with compass at point 12 and radius O-12, the spiral closes upon the eye of the volute.

The Fan Pattern and the Rosette

This introduction to the logarithmic spiral found in the volute brings us around now to my particular area of study, which is the changing nature of paving design in the history of Italian architecture.[4] Usually seen as a minor decorative art, pavements often shed new light on concepts of mathematics and space design in any given epoch. Consider that the floor surface is the largest unbroken plane surface in a work of architecture: it can become, practically speaking, a kind of canvas upon which ideas relating to the architecture may be expressed. Designs based upon spirals form a sub-group of pavement designs which I have found especially interesting.

The mosaic pavements of Pompeii demonstrate a range of patterns which seem to suggest a progression of uses of the spiral motif for creating new paving patterns. One pattern is based upon similar curves rotated about the center of a circle, forming a fan pattern (Figure 4).[5] One example of such a pattern is found in Faenza, Italy, in the mosaic pavement of the Aula del palatium (Figure 5).

A next step beyond the fan pattern involves reversing the direction of the curves and then superimposing the new set of curves upon the first set. This produces a set of curvilinear regions which, when rendered in two colors, forms a design of concentric bands of curvilinear triangles (Figure 6).[6] Because Albrecht Dürer refers to a circular design of this sort as a "rosette"[7], I have come to call this whole class of related designs by this name. A Roman example of such a design is found in a pavement discovered during the excavations of Pompeii, and dated to the first century B.C. (Figure 7).[8]

An even earlier Greek pavement with the rosette pattern may have existed: one plan of the Tholos, or round temple, at Epidaurus in Greece, dated 350 B.C., shows a pavement design based upon the rosette, but it is unclear whether it is original or reconstructed.[9] A medieval example of the rosette may be found in a decorative insert in the pavement of the Baptistery of Florence (Figure 8).[10]

In the Renaissance, rosettes seems to have enjoyed special favor. In Florence, a rosette pattern is found in a panel of the pavement in the Cathedral, while the Sacristy of the church of S. Spirito is entirely covered by a rosette pattern. In the sixteenth century, Michelangelo is credited with the design of two pavements featuring rosettes, that of the Laurentian Library in S. Lorenzo in Florence and that of the famous Campidoglio or Capitol in Rome.[11] Architectural theory of the Renaissance placed particular importance on centrally-planned churches, identifying the center point of the space with the Creator of the cosmos. This emphasis on center may explain the frequent application of the rosette in pavement designs. As a motif with strong visual references to its center, it communicates in a clear way the importance of this point in the architecture to the observer who moves through the space.

Logarithmic and Circular Rosettes

A cleverly constructed optical design created by British psychologist J. Frazer and reproduced in Ralph Evans' *Introduction to Color* illustrates in a striking way the relationship between the rosette pattern and the spiral.[12] In this figure, when concentric circles represented in two colors are superimposed upon a rosette design, a strong optical illusion of a logarithmic spiral is created. But, reader beware, it must be pointed out that although the basic rosette pattern is easily identified, not all rosettes are constructed the same way, that is, only some of them are constructed using a genuine logarithmic spiral. The others are constructed using a "shortcut" method which looks like it is formed of spiraling curves, but has the advantage of being much more quickly constructed. Sebastiano Serlio, architect and theoretician of the sixteenth century, was candid in admitting that, for its aesthetic effect, architecture is dependent upon workmen whose good fortune exceeds their skill, lamenting the difficulty of explaining complicated constructions to unlearned laborers. Perhaps it is for this reason that a shortcut for constructing the ancient and oft-repeated rosette design gained popularity. The shortcut method is based upon a simply constructed set of circles, which we shall examine in some detail presently. But first, how can one tell the difference between a logarithmic rosette

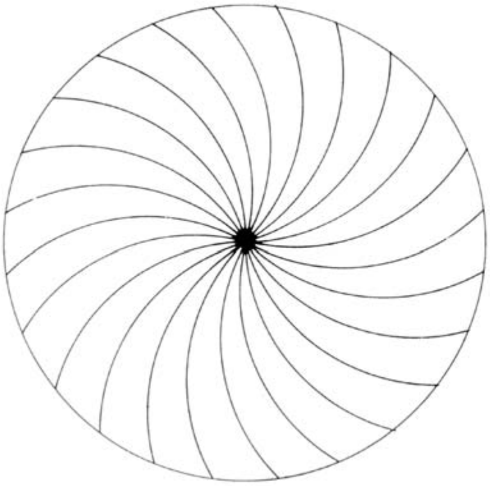

Figure 4.
The fan pattern

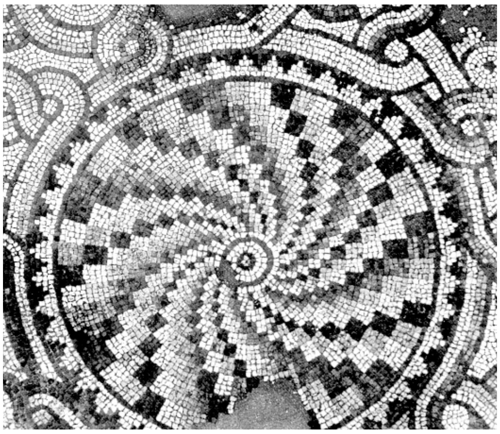

Figure 5.
The fan pattern in the mosaic pavement of the aula del palatium, Faenza, Italy.

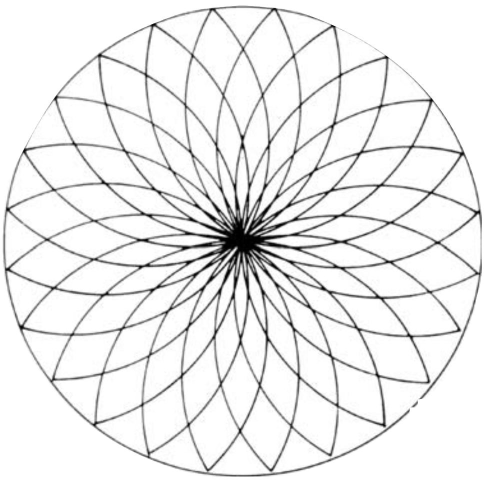

Figure 6.
The rosette pattern

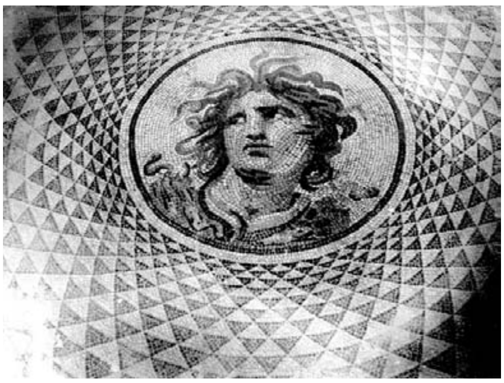

Figure 7.
The Pompeii rosette pavement panel

and a circular rosette? The answer lies in the proportions of the interstices created by the overlapping curves. If the interstices grow larger as they move further away from the center of the design but remain of the same proportions, then the rosette is based upon a true logarithmic spiral. A circular rosette creates interstices which change in both size and shape according to their location in the design. Compare now the Pompeii rosette (Figure 7) with that of the Baptistery of Florence (Fig. 8) Though they are colored in the same way, the difference in the configuration of the curvilinear triangles is clear.

Construction of the circular rosette

The construction begins with the establishment of a "reference circle" to define the outer limit of the rosette. Next, the reference circle is divided into a number of segments by radial lines passing through the center; the greater the number of radials, the denser the rosette. In the next step, a "centrum ring" is determined, a circle concentric with the reference circle. Finally, the "radial circles" are drawn, one for each radial, the center of which lies at the intersection of the centrum ring and the radials (Figure 9). There will be, obviously, as many radial circles as there are radial lines; their overlapping creates the modules of the rosette. Proportions of the modules of the rosette depend upon the relationships between the reference circle and the radial circles. Albrecht Dürer constructed the rosette for a wooden pavement in 1525.[13] In his design, the diameter of each of the twelve radial circles, as well as that of the centrum ring, is equal to the radius of the reference circle. Using the same proportions but doubling the number of radial circles produces a denser rosette.

Three further examples illustrate the relationships between the elements of the construction. Where the perimeters of the radial circles pass through the center of the reference circle, a flower-like shape is created in the center. Where the diameter of the radial circles is greater that the radius of the reference circle, an empty inner circle is formed. For instance, in a rosette where the diameter of the radial circles is equal to 6/10 of that of the reference circle, while the diameter of the centrum ring is equal to 4/10 of the diameter of the reference circle . By increasing the diameter of the radial circles to 2/3 of the diameter of the reference circle (and decreasing the diameter of the centrum ring to 1/3 of the diameter of the reference circle) the centrum ring can be made to coincide with the circumference of the empty inner ring . The greater the ratio of the diameter of the centers of the radial circles to the diameter of the reference circle, the greater the diameter of the empty inner circle. In a last example, the diameter of the radial circles is equal to 3/4 of the diameter of the reference circle (while the diameter of the centrum ring is equal to 1/4 of the diameter of the reference circle); the diameter of the centrum ring is now smaller than that of the empty inner ring.

It may be noted in all cases that the diameter of the centrum ring is always equal to the diameter of the reference circle minus the diameter of the radial circles. This property of the circular rosette construction is helpful when analyzing an existing rosette to determine its structure.

The empty inner ring created within the rosette design is one key to its appearing to be formed out of overlapping logarithmic spirals, for the inner ring then reads as the eye upon which the curve appears to close. But in order to accomplish fully the illusion that the design

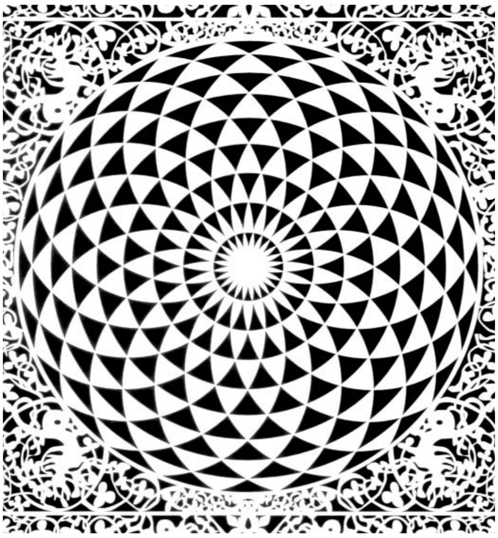

Figure 8.
The rosette panel in the Baptistery of Florence.

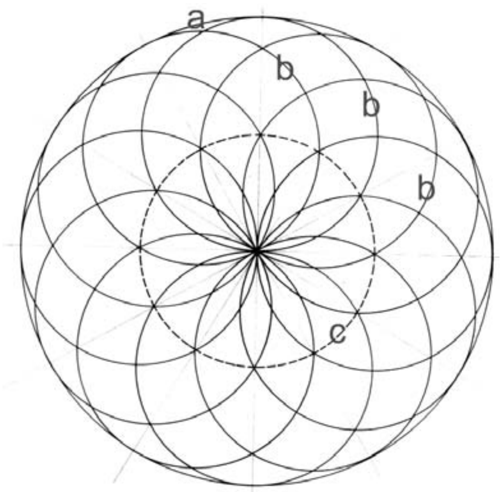

Figure 9.
The rosette proposed by Dürer and the elements of the rosette: a) reference circle; b) centrum ring; c) radial circles.

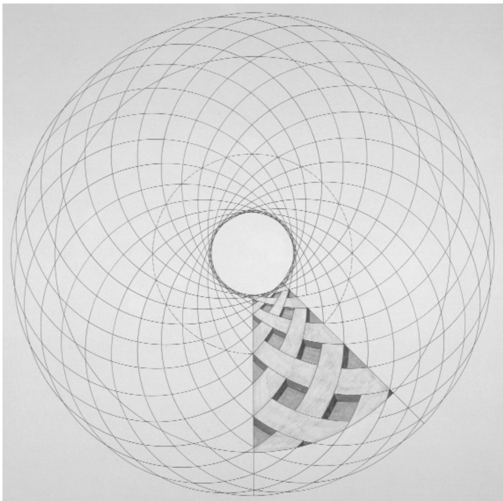

Figure 10.
Basket weave panel from the pavement of the Cathedral of S. Maria del Fiore, Florence.

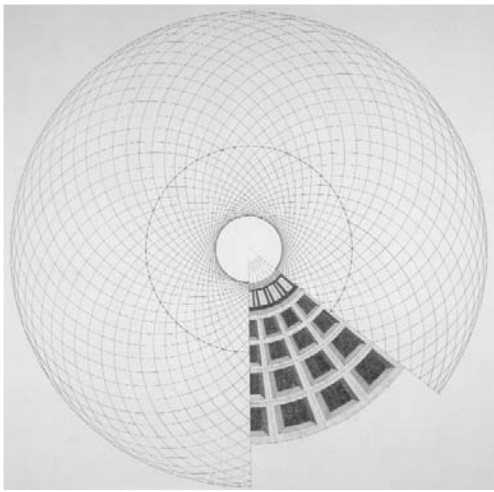

Figure 11.
“Coffered” design derived from the rossete.

is constructed of logarithmic spirals, the rosette must be cut off before the interstices may be seen to decrease. This is indeed how the rosette is treated in almost all pavement designs I have studied. The reader will notice that in the circular rosette, the interstices created by the overlapping radial circles increase in size as they move further from the center up to a certain limit (changing all the while in proportion, as we noted earlier), at which point they begin to decrease in size as they near the circumference of the reference circle. In the true logarithmic rosette, the interstices do not decrease in size, but constantly increase.

Articulation of the Rosette

One property of the rosette which makes it valuable as a graphic device is that the basic rosette may be articulated through the use of color in such a way as to produce designs of varying character. The simplest use of color in the pattern is found when two colors are applied to alternating interstices, resulting in a sort of spiraling checkerboard. This is how the pavement of the Tholos in Epidaurus is depicted. Perhaps the most common treatment is to use two colors, one for the bottom half of each interstice and one for the top half. This is found in the Roman mosaic pavement as well as in the Baptistery of Florence. A more complex color treatment is used in the paving panel in the Cathedral of Florence, where contiguous groups of three interstices form strips which are interwoven to produce a basket weave design. Depth is then added to the design by adding a shadow line. Michelangelo's Laurentian Library pavement panel is similar to the basket weave found in the Florence Cathedral, but the strips which separate the interstices of the design are not created from a single rosette pattern, but rather by the addition of a identical second rosette, the radials of which are rotated slightly away from those of the basic rosette.[14] In addition to its ease of construction and its capacity for variation through the use of color, a third characteristic of the circular rosette recommends its use as a paving design, and that is that it may be efficiently built, as is any pattern that is repetitive. The actual building procedure goes something like this: an artist in the marble working shop draws the pattern and indicates the templates to be cut out of wood; the templates are used to make lines on the slabs of marble; the marble is cut and roughly finished in the shop, then transferred to the site; the marble pieces are assembled on the site like a jigsaw puzzle, set in mortar, and finally, finely polished. Examining the circular rosette of the inset panel in the Baptistery of Florence we can determine by counting that there are 409 pieces in all which compose the panel.[15] However, there are only 18 individual shapes requiring separate templates. An examination of the basket weave panel in the Cathedral of Florence reveals that it is less efficient to build, having an slightly smaller number of pieces, 396, but a greater number of shapes, 25 (Figure 10). Another characteristic of the rosette design is that in addition to producing the interstices which increase and decrease in size, it also produces sets of points which may be joined to form a series of concentric circles with ever-greater diameters. In the circular rosette, the diameters of the circles increases only up to a certain limit, before decreasing to the point where the outermost circle finally coincides with the reference circle. This is analogous to how the interstices of the circular rosette increase in size, then decrease. In the logarithmic rosette, the diameters of the circles continually increase. These concentric circles may serve as a proportional device in the creation of new designs. One such design projects onto the pavement an arrangement of distorted squares such as one might see looking up into a dome articulated by coffers: three concentric rings are separated from one another by ever-greater distances as they move away from the center (Figure 11). The spacing of these rings coincide with those created by a circular-based rosette.

Conclusion

The spiral has been used as a stylized expression of compressive force on architecture elements, as well as the basis for an important group of pavement designs. Both of these have come about as the result of architects' observations of the natural world, a world which has equally fascinated mathematicians. In the construction of the volute and the rosette, the two disciplines are united, producing works of art which can still communicate their truths to us today.

Notes

1. For more about spirals, cf. Philip J. Davis, *Spirals: From Theodorus to Chaos* (Wellesley, Massachusetts: A.K. Peters, 1993); Theodore Cook, *The Curves of Life* (1914, reprinted New York: Dover Publications, 1986).
2. The spiral volute is found also in the Greek Corinthian order, and in the Roman Composite order. For descriptions of all the orders, cf. Robert Chitham, *The Classical Orders of Architecture* (New York: Rizzoli, 1985).
3. Cf. Bannister Fletcher, *A History of Architecture on the Comparative Method*, 12th ed. (New York: Charles Scribner's Sons, 1945), p. 100, fig. Q.
4. Cf. Kim Williams, *Italian Pavements: Patterns in Space* (Houston: Anchorage Press, 1998).
5. Cf. Asher Ovadiah, *Geometric and Floral Patterns in Ancient Mosaics* (Rome: L'Erma di Bretschneider, 1980), p.153.
6. Cf. Asher Ovadiah, *op. cit.*, p. 144.
7. Cf. Albrecht Dürer, *The Painter's Manual.* Walter L. Strauss, trans. (New York: Abaris, 1977), p. 153 and fig. 21.
8. This pavement panel is now on display in the National Museum, Rome.
9. Cf. Cyril Harris, ed., *Historic Architecture Sourcebook*, 1977, reprinted as *An Illustrated Dictionary of Historic Architecture,* (New York: Dover Publications, 1983), illustration under heading "Tholos," p. 531.
10. The pavement of the Baptistery of Florence is interesting as a geometric study in itself. Cf. Kim Williams, "The Sacred Cut Revisited: The Pavement of the Baptistery of San Giovanni, Florence" in *Mathematical Intelligencer*, Vol. 16, no. 2 (Spring 1994), pp. 18-24.
11. The rosette of this last is framed by an ellipse rather than a circle.
12. This figure appears in Harold Jacobs, *Mathematics, A Human Endeavor,* 2nd ed., (New York: John Wiley and Sons, 1980), p. 351.
13. See note 7.
14. For more about this pavement, cfr. Ben Nicholson and Jay Kappraff, "The Hidden Pavement Designs of the Laurentian Library" in *Nexus II: Architecture and Mathematics,* Kim Williams, ed. (Fucecchio, Florence: Edizioni dell'Erba, 1998), pp. 87-98.
15. I count the star-shaped piece in the center as one piece and one shape.

About the Author

Kim Williams, director of the Nexus conferences on architecture and mathematics and editor of the *Nexus Network Journal*, is an American architect living and working in Tuscany. She received her degree in Architectural Studies from the University of Texas in Austin, and was licensed as an architect in New York State. Author of *Italian Pavements: Patterns in Space* (Houston: Anchorage Press, 1998), she has published several articles on the use of mathematical principles in architectural monuments and in paving designs in journals such as *Mathematical Intelligencer* and *Leonardo*. Her research has been supported by grants from the Graham Foundation for Advanced Studies in the Fine Arts and the Anchorage Foundation of Texas.