

Leonardo da Vinci's architectural designs as thought experiments: the sources and influence of his ideas

Estelle Alma Maré

Department of Architecture, Tshwane University of Technology, Pretoria

E-mail: mare_estelle @ fastmail.fm

It is argued that Leonardo da Vinci's architectural designs are uniquely original due to his ability to connect ideas derived from a wide range of sources and his own empirical researches. This attempt at understanding Leonardo's visual thinking that is the basis of his architectural designs commences with a reference to his decorative knotted puzzle, entitled *Concatenation*, that symbolises a map of the universe, reminiscent of Aristotle's world view, as expressed by Dante Alighieri. Leonardo's empiricist approach to scientific research and artistic creativity also relates to Aristotle's insight into matter, form and growth patterns. His creative process in art and design was inspired by thought experiments in which his mastery of *disegno* enabled him to express the mutation of living forms into mechanical and architectural forms, and *vice versa*, to imbue the latter with a life force. His representation of fictive buildings in his paintings is surveyed, followed by a review of his architectural sketches of which his designs of centralised and longitudinal domed churches are evaluated in some detail, taking into account his varied sources as well his influence. Emphasis is placed on Leonardo's originality as an architectural designer, especially with reference to notable domed churches on octagonal plans with side chapels that approximate fractal designs.

Key words: Leonardo da Vinci's architectural designs, thought experiments, *disegno*, domed churches, fractal design

Leonardo da Vinci se argitektoniese ontwerpe as gedagte-eksperimente: die bronne en invloed van sy idees

Dit word aangevoer dat Leonardo da Vinci se argitektoniese ontwerpe op 'n unieke wyse oorspronklik is vanweë sy vermoë om idees wat van 'n wye verskeidenheid bronne en sy eie empiriese navorsing verwerf is, met mekaar in verband te bring. Hierdie poging om Leonardo se visuele denke wat die grondslag van sy argitektoniese ontwerpe is, te begryp, begin met 'n verwysing na sy dekoratiewe, geknoopte raaisel, genaamd *Samekoppeling*, wat 'n kaart van die heelal simboliseer en herinner aan Aristoteles se wêreldbeeld, soos deur Dante Alighieri verwoord. Leonardo se empiriese benadering tot wetenskaplike navorsing en kunsskepping hou ook verband met Aristoteles se insig in materie, vorm en groeipatrone. Sy skeppingsproses in kuns en ontwerp is geïnspireer deur gedagte-eksperimente waarin sy meesterskap van *disegno* hom in staat gestel het om voorstellings te doen van die mutasie van lewensvorme in meganiese en argitektoniese vorms, en omgekeerd, ten einde laasgenoemde met 'n biologiese vormingskrag te vervul. Sy voorstellings van denkbeeldige geboue in sy skilderye word nagegaan, gevolg deur 'n oorsig van sy argitektuursketse, waaronder sy ontwerpe van gesentraliseerde en langwerpige koepelkerke meer gedetailleerd ontleed word, met inagneming van sy gevarieerde bronne sowel as sy invloed. Klem word geplaas op Leonardo se oorspronklikheid as 'n argitektoniese ontwerper, veral met verwysing na die uitsonderlike gesentraliseerde koepelkerke op agthoekige planne wat by benadering as fraktaalontwerpe bestempel kan word.

Sleutelwoorde: Leonardo da Vinci se argitektoniese ontwerpe, gedagte-eksperimente, *disegno*, koepelkerke, fraktaalontwerp

Thought experiments are devices of the imagination used to investigate the nature of things (Brown 2011: 1).

The logical pattern of the creative process [...] consists of the discovery of hidden similarities (Koestler 1970: 27).

Leonardo da Vinci's architectural designs have been taken seriously as part of the history of architecture by various researchers who have dedicated and continue to dedicate books, chapters in books and scholarly articles to the subject, but few have noted the extensive range of varied ideas incorporated into his designs.¹ It is therefore the purpose of this article to attempt to take into account his sources and influences, emphasising his originality as an architectural designer in connecting disparate ideas related to his own empirical researches.

Originality and creative thinking in both the realms of science and art is seldom combined in the researches and creative manifestations of one person, as in the case of Leonardo da Vinci (1452-1519). Since creativity as a symbolic activity is sustained by the imagination, the geometrical obsessions that dominated Leonardo's last years (Kemp 1996: 186) were the product of a fervent imagination experimenting with forms that would represent visual symbols – some of which are architectural designs, dealt with in this article. The objective of this research is to explicate how such symbols reflect a world view, and furthermore to analyse how a range of thought processes connecting in the various expressions of Leonardo's architectural designs, prove the postulate that “the logical pattern of the creative process [...] consists of the discovery of hidden similarities” (Koestler 1970: 27).

Leonardo's *Concatenation* as a symbolic map of the universe

This analysis of Leonardo's visual thinking as an empiricist and creative artist commences with an analysis of a decorative knotted puzzle, entitled *Concatenation*, that he designed as a logo (probably executed by his pupils), intended to be his “hieroglyphic signature” (Goldscheider 1959: 12). Since knotted designs pervade Leonardo's oeuvre it is important to focus on the meaning of this symbolic puzzle that takes on the form of a circular pattern, consisting of a single unbroken white line meandering on a black background, containing the words *Academia Lionardi Vici* in the centre, with four angle ornaments (probably derived from Medieval and Renaissance maps) in the form of knots (figure 1).



Figure 1
Leonardo da Vinci, *Concatenation*, engraving, circa 1499-1500,
British Museum, London (source: <http://www.nordicneedle.com>).

The form of Leonardo's *Concatenation* design may have various precedents. It could be derived from nature in which the sunflower produces a centralised spiralling pattern. Leonardo illustrated his observation that "Water struck by water forms circles around the point of impact",² showing in each swirl the calm eye around which the water expands and contracts as representing the still place where dynamic opposites meet in a gravitational centre, similar to the central "eye" in the *Concatenation* (figure 2). Leonardo most probably also studied the rose window of the Cathedral of Santa Maria del Fiori, Florence, with its centralised pattern. He may also have been aware of Muslim designs that display a remarkable geometry that often encloses a centre in an intricate pattern.



Figure 2
Leonardo da Vinci, detail from a page of sketches of swirling water, 1507, Royal Library, Windsor Castle, no. 12662r (source: Zöllner: 443).

The first art historian to point out a probable literary influence on Leonardo's *Concatenation* was Ananda Coomaraswamy (1944: 114). He postulated that it represents a map of the universe in the precise terms of Dante Alighieri's (1265-1321) lines in *Paradiso* XXIX: 31-6:

Concreto fu ordine e costruito
 e la sustanze; e quelle firon cima
 del mondo in che puro prodotto;

pura potenza tenne la parte ima;
 nel mezzo strinse potenza con atto
 tal vime, che già mai non si divima.

(At the same time as substances were created, was their order [hierarchy] created and firmly established. And those were placed in the highest rank which possess pure act [intelligence]; those who possess potentiality [matter] occupy the lowest station; in the middle part [i.e. between the lowest – the sublunar, and the highest – the Empyreum], a bond, which can never be loosened, conjoined act with potentiality [to form the heavens].)

Since the bond – a knot – between the hierarchy of substances can never be loosened, Dante states in *Paradiso* XXXIII: 58-60:

Si li tuoi non sono a tal nodo
sufficienti, non è maraviglia;
tanto per non tentare è fatto sodo!

(If your [Beatrice's] fingers are not skilful enough [to unravel] such a knot, it is no wonder; it has become so tight, since no one has attempted [to unravel] it.)

The following lines, from *Paradiso* XXXIII: 91-3, may also have influenced Leonardo's thinking:

La forma universal di questo nodo
credo ch'io vidi, perché più di largo
dicendo questo, mi sento ch'i godo.

(This universal form of the knot [closely knit bond] I think I saw; for while I am saying this, I feel I experience such a deep joy.)³

The implication in Dante's lines is that a puzzle is like a knot that defies unravelling. This idea would have appealed to Leonardo whose artistic oeuvre abounds in ambiguity and multiple meanings. A connection can be made between the *Concatenation*, if it is interpreted as the plan of a metaphysical map representing his world view, and Dante's idea that God is He who draws the earth and unites it to himself (notwithstanding the poet's confession that he does not understand the different elements' circular movements in the divine and terrestrial spheres). Thus, Leonardo's design has three parts, corresponding to Dante's "highest" (the summit), "middle", and the "lowest", of which the first and last are white. The dark background in the engraving represents earth, with angle ornaments most probably meant to be indicative of the cardinal directions, like on a map. Seen from below the knotted tissue broadens out below and contracts above, forming a design of seemingly self-creating unity. The knot as a puzzle is most probably a motif that reveals Leonardo's invocation of the power of problem solving by means of thought experiments: formulating puzzles and solving them visually, always with the end in view "to investigate the nature of things" (Brown 2011: 1), especially in his architectural designs that most often also have three parts.

Also in Leonardo's creative work knots are found, for example along the upper edge of the sitter's black bodice in Leonardo's *Mona Lisa*⁴ where the artist drew countless knotted cloverleaf patterns in a wickerwork design. Since wickerwork is *vinco* in Italian, the artist most probably intended the knots as a reference to Vinci, his birthplace.⁵ Also in the ceiling decoration in the Sforza Palace in Milan knots proliferate (figures 3-4), echoing his "hieroglyphic signature".

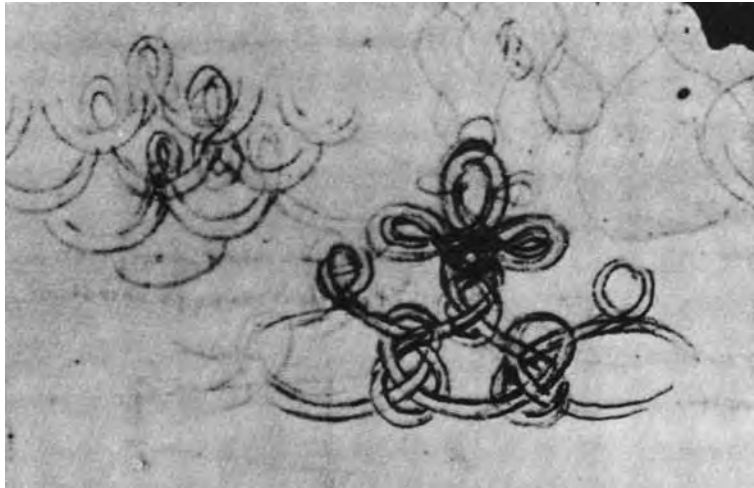


Figure 3
Leonardo da Vinci, study of knots, red chalk on paper,
Royal Library, Windsor Castle (source: Reti 1974: 37).



Figure 4
Leonardo da Vinci, fresco decoration in the Sala delle Asse,
Sforza Palace, Milan 1496-97 (source: Reti 1974: 37).

Even though there is an innovative strangeness in Leonardo's visually expressed world view, it is rooted in knowledge of his time, albeit restructured by his scientific enquiry into reality. The *Concatenation* is symbolically bound by a cosmology of circular and precisely unified forms that may imply erroneously that Leonardo, like Dante, had not progressed from the concept of a closed universe, as postulated by Aristotle (384-322 BCE), to an infinite universe (Koyré 1969). However, the self-creating unity of his design, mentioned above, is, according to D. Wade (1991: 276), more characteristic of the present view of the cosmos as "dynamic, self-creating, self-influencing" than of Leonardo's time. Furthermore, Leonardo affirmed the value of perspective: "Perspective, which shows how linear rays differ according to demonstrable conditions, should therefore be placed first among all the sciences and disciplines of man, for it crowns not mathematics so much as the natural sciences."⁶

Matter and form

In Classical Greek philosophy the problem of motion hangs together with the opposition of oneness of being and the multiplicity of existence. J. Marías (1967: 71) explains Aristotle's thinking as follows: "Moving and changing is a coming to be and a ceasing to be. Motion is [...] the realization of the possible in so far as it is possible." In short, motion implies the passing of one mode of being to the other.

Leonardo's understanding of matter and form as "the structure of things" was derived from Aristotle's *Metaphysics* (written 350 BCE) in which it is claimed that substance is a composite of two elements: "Form is the act of the matter, the perfection by which matter is something" (McCue 1962: 3). Matter is that of which a thing is made; form is that what makes a thing what it is. Form is that which confers being, for example the form of a table can be imposed on wood. Matter is simply possibility; it is potential that can be actuated.⁷ By analogy, this insight has relevance for Leonardo's art and architectural concepts, especially when considered in relation to the expression of the motion that shapes organic growth patterns.

In the greater part of Leonardo's oeuvre as a designer, his thought experiments involved the mutability of forms, expressed by means of his mastery of *disegno*.

Disegno

Leonardo's search for an optimal solution for innovative design forms is expressed by means of *disegno*. This term is not the exact equivalent of "design" in English, but refers to the sketch, the drawing or exploratory phase of a visual work of art, including architectural and engineering designs.⁸ All Italian Renaissance artists were draftsmen, first and foremost. However, *disegno* was not only related to the delineation of forms, but the planning of entire compositions. However, this procedure was not identical for all the arts. Leon-Battista Alberti (1988) noted that the architect, compared with the painter, "desires his work to be judged not by deceptive appearances but according to certain calculated standards."

So important was *disegno* or creative drawing that characterises the working method of Renaissance artists, that the concept acquired Neoplatonic connotations. The concept of creativity as the realisation of an Idea is Neoplatonic, a philosophy derived from Plotinus (204-70 CE), based on Platonic ideas. According to Federico Zuccaro (1541-1609), the sixteenth-century Italian painter and theorist, it actually meant "the sign of God in us" – that is in the artist. Indeed, it was believed that Renaissance artists, such as Leonardo, Raffaello Sanzio (called Raphael in English, 1483-1520) and Michelangelo Buonarroti (1475-1564), were endowed with

geniality and divinely inspired. Giorgio Vasari (1511-74) actually called these artists divine (*divino*). The Italian humanists of the early Renaissance and sixteenth century established Neoplatonism as the norm and reconciled it with Christian beliefs that influenced artists. A case in point is Michelangelo, who in the figures called *Slaves* for the tomb of Pope Julius II (1513-16), depicted their spiritual struggle against the inertia of matter. However, this kind of expression was foreign to Leonardo's vision of reality. Even though he alluded to Neoplatonic ideals, Martin Kemp (1981: 106) quotes his assertion, "All our knowledge has its foundation in our sensations", as an assertion strongly flavoured by Aristotelian empiricism. Kemp (1981: 128) also states: "The Platonists' introverted quest for truth within man's soul was denounced as vigorously as possible by Leonardo – he believed fervently that 'knowledge' which the Platonists claimed to possess could never be verified against objective truth, because their 'knowledge' could only 'begin and end in the mind'."

Leonardo was basically an empiricist and indebted to Aristotle in his scientific thinking. In his artistic theory he echoes Dante's insight, that "art must begin in the mind before it can issue through the hands" (Leonardo 1956: 35). In this he followed an essentially Aristotelian view of art, as expressed by Dante in his treatise *De monarchia* (2.2): "Art exists in three degrees: in the mind of the artist; in the instrument as technique; in the material potentiality as informed substance." However, in Codex Urbino (folio 50r and 116r), Leonardo emphasises the unique quality of *disegno*: "Design [*disegno*] is of such excellence that it not only studies the works of nature but is more infinite than those made by nature [...] and, on account of this, we conclude that it is not only as science but a divine power."⁹ Moreover: "[*Disegno*] surpasses nature because the basic forms of nature are finite and the works that the eye demands of the hands are infinite."¹⁰ In Leonardo's scientific thought *disegno* enabled him to be a "tireless inventor of new things", as his one-time collaborator, Luca Pacioli (1446/7-1517), characterised him.¹¹

Disegno in Renaissance visual arts relates mainly to form, in contrast to *invenzione* which deals with content.¹² However, "The imagination of the painter gives life to a new *invenzione* with the help of *disegno*" (Zwijnenberg 1999: 25). The practice of *disegno* moreover encompasses the "total configuration of a painting without connections of colour. By implication, form in this broad sense included the individual form of all components of the painting" (Poirier 1976: 28), and – by extension – of a building. There is a dynamism and dialectic of opposites, of reality and fantasy, in Leonardo's manner of practising *disegno* in the creation of a work of art. An example is the calm serenity of the posed figure in the foreground of the *Mona Lisa*, compared with the powerful, almost volcanic backdrop.

Indeed, Leonardo seems to have been preoccupied with the dialectic between various forms and their mutability. In his fresco depicting the *Battle of Anghiari* (figure 5) the head of a horse, represented in an attacking mode with bared teeth, is comparable to a ferocious human face. Mutability of a pattern is also seen in various sketches, for example of swirling water (figure 2) and plaited hair. Some of Leonardo's flying machine designs look like bat wings, while Kemp (1987: 131-2) notes that others resemble his drawing of a skeletal human hand. His idea of redesigning Milan as a healthy city by creating more space between buildings for wider roads is an anatomically based "circulatory system".¹³ Leonardo also envisaged a colossal bridge over the Golden Horn in Istanbul, reminiscent in form of the arched body of a man supporting himself on his outstretched arms and legs (figure 6).¹⁴

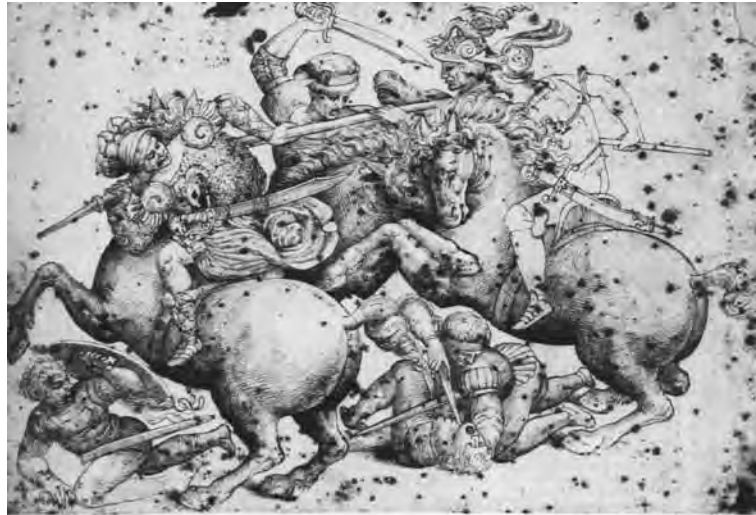


Figure 5
 Leonardo da Vinci, detail of the *Battle of Anghiari*, 1503-5, a detail copied by Peter Paul Rubens, black chalk and white highlights, Royal Library, Windsor Castle (source: <http://www.wga.hu/support/viewer/z.html>).



Figure 6
 Leonardo da Vinci, design for a bridge over the Golden Horn, Istanbul, circa 1502, manuscript L, folio 66 recto (source: Reti 1974: 266).

As will be noted below, his anatomical studies and architectural sketches, as well as the proportions of the human body and that of a building have the same quality of mutability. Leonardo's *disegno* skills enabled him to transmute the pattern of one basic form into a series of more diverse forms that has the quality of a scientific formula in the progression from the simple to the intricate. Thus, Leonardo was an empiricist who made no real division between his researches into science and art, resulting in an oeuvre characterised by his ability to mutate living forms into design forms such as machines and buildings.

Fictive architecture in Leonardo's paintings and his use of perspective

In his paintings Leonardo left a legacy of architectural representation that broadens our understanding of his design ideals. Practising architects of his day may well have learnt from the way in which he applied perspective to architectural compositions as settings for human figures and their actions.

Though not displaying a full facade, or even a distant view of a complete structure, the architectural backdrop behind the Virgin in the *Annunciation*, an early painting (circa 1472-5), reveals a most intricate wall that has no parallel in Florentine Renaissance palace architecture (figure 7). The most impressive architectural details in the wall structure are the massive quoins rendered in dressed ashlar or marble that defines the dimension of the wall. Both the partially glimpsed doorway and the angled corner framing the Virgin are set in an otherwise unarticulated wall surface with its smooth, painted stucco finish, forming a strong contrast with the quoins.



Figure 7
Leonardo da Vinci, *Annunciation*, 1472-75, tempera on wood, 98x 217 cm
(source: <http://www.wga.hu/index1.html>).

In the painting the quoins have a direct relevance for its perspective structure. If continued, their horizontal lines converge in a vanishing point in the painting's background. Compositionally the architectural treatment contributes to the creation of an orderly setting in which the positions of the figures of the angel and the Virgin as well as every surrounding and background element are fixed. This implies that the plan of the palace, of which but a small part is revealed in the composition, can be accurately plotted.

The overall treatment of the fictive wall in the *Annunciation* is not found in buildings by Filippo Brunelleschi (1377-1446) or Leon Battista Alberti (1404-72), who often used heavily rusticated quoins to frame a rusticated wall. Leonardo's treatment of his depicted wall would seem to prefigure the use of quoins in buildings by Giacomo da Vignola (1507-73) and later Baroque architects who likewise contrasted the stone texture of the quoins with the smooth surface of stuccoed walls.

The architectural setting for the Bible narrative relating to the arrival of the Magi at the place of Jesus's birth in the *Adoration of the Magi* is complex (figure 8). The preparatory sketch actually shows multiple stairways built over arched passageways that ascend to an upper terrace, crowded with spectators. In the unfinished painting this space is rendered as a blank wall

connected to a series of broken arches and vaults. The scale of the wall, its prominent location and enigmatic function seem to have a purpose in the perspective construction of the painting in which each figure and object has a fixed place on a reconstructed plan. However, the overall impression is of a dialectic of movement, of people and animals amidst architectural structures transmuted into ruinous, jagged and somewhat purposeless forms.¹⁵

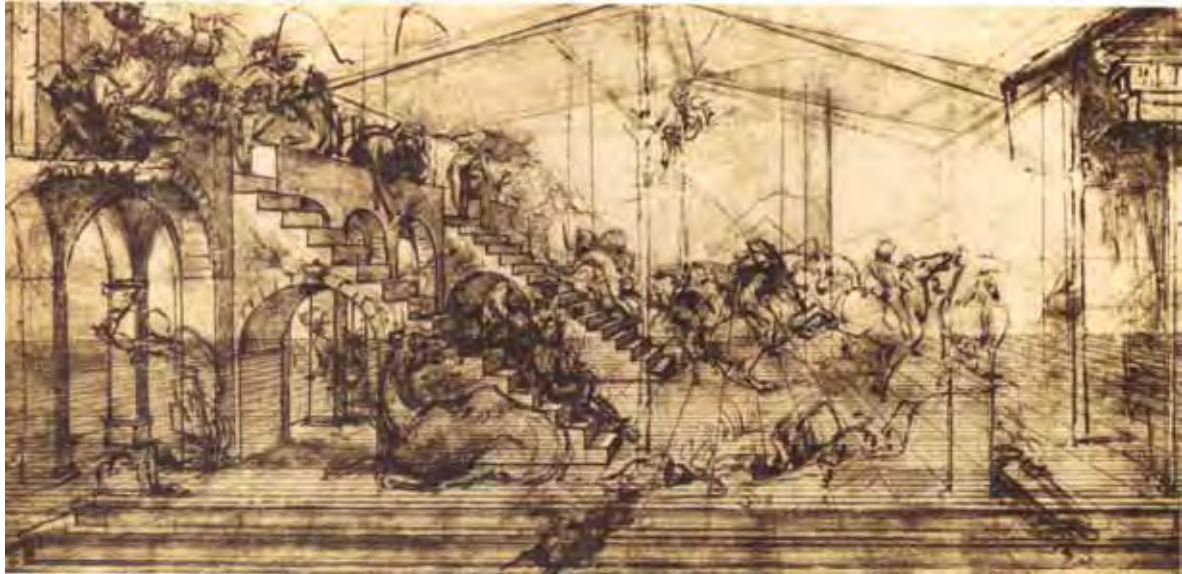


Figure 8

Leonardo da Vinci, preparatory sketch for the background of the *Adoration of the Magi*, circa 1481, metalpoint reworked with pen and brown ink, brush and brown wash on light brown prepared paper, 16,3x29 cm, Galleria degli Uffizi, Florence (source: <http://www.wga.hu/index1.html>).

If the setting of the *Annunciation* seems unreal and ambiguous, Leonardo painted a perfectly proportioned interior in the *Last Supper*¹⁶ in the refectory of San Ambrogio, Milan during the years 1495-97. The upper room, as an illusionary extension of the refectory in which the *Last Supper* is represented. As befitting his status, the figure of Christ is placed in the precise centre of the composition that is mathematically set out according to a perspective formula about which scholars have differences of opinion. The inclining side walls of the Last Supper room that are a continuation of the side walls of the refectory, are divided by four evenly spaced rectangular panels depicted on the side walls and three openings in the rear wall, the central one larger than the sidelights whose lintels are set somewhat below the level of the side wall panels. The central window is crowned by a segmental pediment that also serves as a sort of half-halo behind Christ's head. This geometric precision that results in a kind of classical, formal purity is different from the somewhat chaotic setting of the sketch for the *Adoration of the Magi*.

Summing up Leonardo's representations of fictive architectural structures and space in his paintings, D. Fricelli (1993: 510) refers to "the protean nature of his architectural imagination, which seems to encompass [...] the development of Italian architecture from Bramante through Palladio".¹⁷

A summary of Leonardo's civic designs

Kemp (1996: 194) describes Leonardo's architecture as "in the spirit of Brunelleschi, combining a reverence for the proportional principles of antique buildings (as expounded by Vitruvius [80-

70 BCE-after 15 BCE]) with a relatively undogmatic use of the classical vocabulary and an inventive ingenuity in matters of engineering”. Leonardo’s approach to architecture was not only aesthetic, that is with emphasis on the formal appearance of the composition of the building, but his sketches also suggest an understanding of structure. No better example can be quoted than Leonardo’s definition of arch as “a force originated by two weaknesses, for the arch in buildings is composed of two segments of a circle, each of which being very weak in itself tends to fall; but as each opposes the tendency in the other, the two weaknesses combine to form one strength” (Richter 1880: 778). Even though this is not an original insight, Leonardo searched for qualitative insights into the nature of building construction. His enquiring mind initiated new methods of structural research, albeit by means of thought experiments, summed up by George Winter (1963: 303): “It is the method of approach of Leonardo’s investigations which marks the turning point from traditional art to scientific structural engineering. His subjects included beams, columns, arches, trusses, wires. Toward all of them he had a dual approach: investigation by experiment, and an application of the science of mechanics to structural problems in an attempt at quantitative calculation.”

Leonardo was not a practising architect; however, he produced sketches of a large number of building plans and elevations, urban schemes, proposals for architectural details, as well as for monumental constructions, which are best interpreted as “units of his creativity” (Dorn: 1998: 523). Most notable are the sketches for longitudinal and domed churches with chapels (to be dealt with in the next section), public buildings, a palace, fortifications, the architectural regulation of entire regions, a garden and a pavilion. It is doubtful if any of his schemes were ever executed and it is also difficult to trace his exact influence on other architects. It is nevertheless apt to refer to Leonardo’s architectural schemes as “his inquiry into the possibilities offered by architecture, both as an art and a science” (Fricelli 1993: 509).

In 1487 Leonardo was in Milan where he prepared a model for the *triburio* over the crossing of the city’s vast Gothic cathedral. He attempted to devise a structure with affinities to the Gothic ribs of the cathedral, but the project was never executed. This design was clearly indebted to the crossing structure Brunelleschi devised for Florence Cathedral. However, it is most interesting that in his submission to repair a structurally defect cathedral he refers to the healing of a sick person who suffers from a lack of maintenance of “a parity and concordance of the elements [that] maintains it”,¹⁸ thus linking the wellbeing of a person with the soundness of a physical structure.

Fricelli (1993: 509) points out that in the expression of his architectural ideas, “Leonardo spoke not the language of the Florentine Renaissance of Brunelleschi and Alberti, but rather the fully developed, classically inspired language of the High Roman Renaissance of Bramante.”¹⁹ In a proposal for a church facade Leonardo not only anticipated Michelangelo’s design for the elevation of San Lorenzo Cathedral, Florence, but also the facades of later churches by Andrea Palladio (1508-80), as well those by the Baroque architects Carlo Maderno (1556-1629) and Gian Lorenzo Bernini (1598-1680). In civil architecture Leonardo’s plan for a palace facade anticipated not only Donato Bramante’s (1444-1514) Roman palace style, but that of Raphael as well.

As an engineer Leonardo envisaged a circular fortress consisting of concentric rings of fortifications and moats around a central citadel, with four outposts arranged equidistant around the periphery (figure 9). This innovative design of an enclosed and protective military building echoes the circular form of the *Concatenation* with its four angle ornaments.

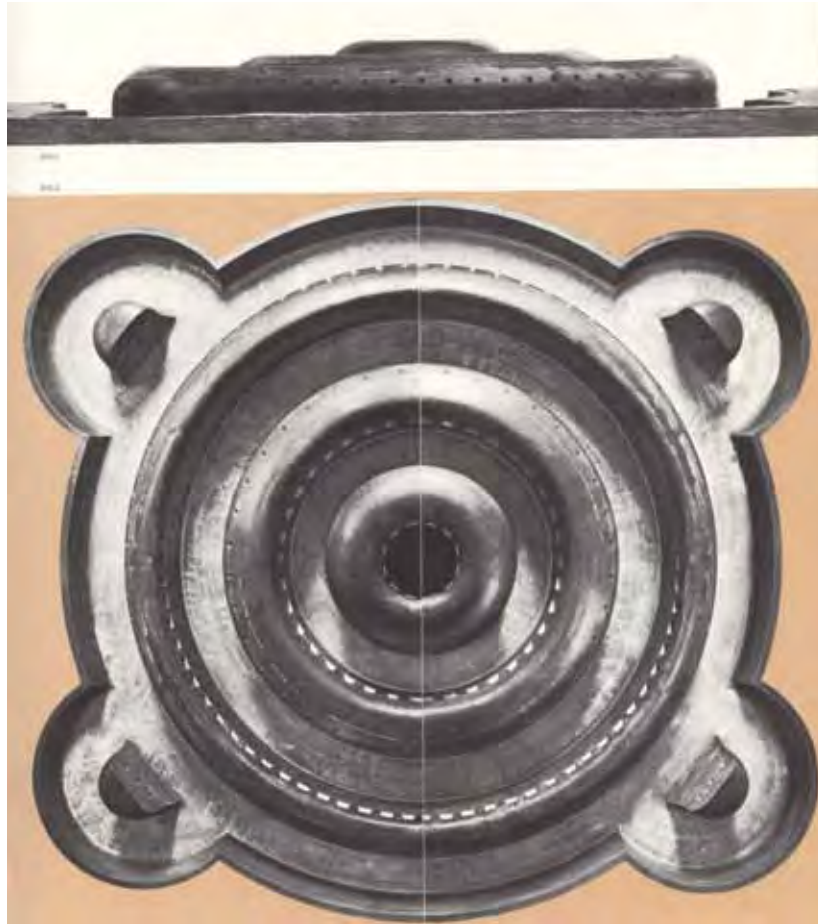


Figure 9
Leonardo da Vinci, model of a fortress with concentric rings, based on a sketch in Codex Atlanticus, folio 48 *recto-b* (source: Reti 1974: 165).

Urban planning as the extension of architecture into the larger environment, was well understood by Leonardo. His proposed scheme for the redevelopment of the area of Florence between San Lorenzo and San Marco would have created a rectangular city space centred on the Medici palace. This scheme was later reinterpreted by Vasari for the urban renewal of the area between the Palazzo Vecchio and the Arno River that resulted in the creation of the Uffizi building and its courtyard passageway, the present Galleria del Uffizi.

Leonardo spent the last three years of his life as guest of Francis I (François Ier, 1494-1541), King of France, who called on him to design an entire new city at Romorantin as a royal residence (figure 10). During his last years at Amboise, Leonardo produced schemes for the new city and an imposing palace. According to Carlo Pedretti (1972) the project was Leonardo's last dream that was, unfortunately, abandoned after his death. However, if it had been built according to Leonardo's designs, it would have been what Karel Vereycken (2010: 53) calls a "first modern city". Its most remarkable feature is its total regularity, parallel streets, intersected at right angles by short, wide cross streets. Leonardo's innovative plan introduced the use of urban canals as part of the city's gridded street system. A long, straight canal bisects the city, while shorter canals, following the cross-streets, cross it at right angles, connecting the central canal to a system of canals that encircle the city as a defensive moat. This clearly articulated urban scheme, being both "utilitarian and salubrious" (Fricelli 1993: 509), anticipated not only the water-gardens of the Italian and French Baroque, but is also reminiscent of the street and canal system of Amsterdam, planned some 200 years later.



Figure 10
Leonardo da Vinci, sketch for the proposed city of Romorantin
(source: Pedretti 1985: 264).

It has been suggested that Leonardo may have designed the Château de Chambord in the Loire Valley for Francis I, since the structure of the remarkable double helix staircase at its centre points to an extraordinary architect (figure 11).²⁰



Figure 11
Attributed to Leonardo da Vinci, double helix staircase,
Château de Chambord, 1519-47 (photograph: the author).

The spiral staircase at the Château de Blois is also attributed to Leonardo since its mathematical calculation of a spiral growth pattern structure also points to an extraordinary architect (figure 12).²¹



Figure 12
Attributed to Leonardo da Vinci, spiral staircase, Château de Blois,
rebuilt by Francis I from 1515-19 (photograph: the author).

Leonardo's sketch for a city centre is on two levels, with a series of tunnels below ground level carrying wagon, cart and horse traffic, as well as serving as a conduit for waste material, and an upper level consisting of a series of arcaded structures framing an interconnected public square and pedestrian sidewalks (figure 13). This novel urban design in which Leonardo envisaged a city that would be practical, aesthetic, and hygienic to promote the well-being of inhabitants in the overcrowded Italian cities of his day, seems to be an urban extension of the traditional Renaissance palace as an architectural unit with its services on the ground level, and the *piano nobile* for luxurious living on the upper floor. Only in the twentieth century in the West did town planners apply similar ideas to separate services, vehicular traffic and pedestrian movement.



Figure 13
Leonardo da Vinci, project for a city centre on different levels,
pen, ink and black chalk, manuscript B, folio 39 *recto* (source: Baroni 1956: 251).

Leonardo cannot be assessed as an architectural and urban planner in terms of actual structures, because he left no such legacy. Rather, some of his proposals for civic structures, churches, a palace, a harbour, and fortifications found somewhat modified expression in the architecture of his contemporaries, notably Bramante, as well as architects of the High Renaissance, both in Italy and later also abroad.

Leonardo's church designs

Continuing the tradition begun by Bramante in the Greek cross design of St. Peter's Basilica in Rome, of which the cornerstone was laid in 1503, Leonardo's thought experiments include a large number of central-plan churches. He envisioned a series of variations on the theme of a church composed of a geometrically regular domed octagonal central hall with side chapels ringing the central area. In these centralised plans the dome, placed on an octagonal base that can be geometrically inscribed in a circle while retaining the suggestion of a circular format, is mostly pointed, ribbed and crowned with a lantern, with much smaller similarly domed side chapels placed on the exterior sides of the octagonal plan (figure 14).

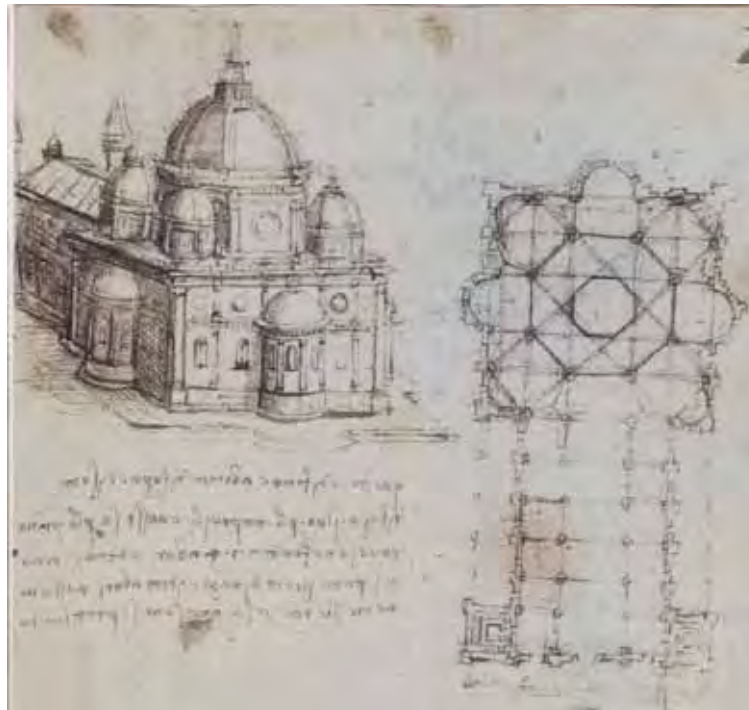


Figure 14
Leonardo da Vinci, plan and elevation of a longitudinal domed church with a central octagonal plan and surrounding domed chapels, manuscript B, folio 24 recto, pen, ink and black chalk (source: Chierici 1956: 236).

A variation of the domed central church is a Greek-cross plan with an octagonal central area, surrounded by eight side chapels of different forms, crowned on the flat roof structure with alternate turrets and small domes, entered with a stairway on the outside to a second level (figure 15). The corner turrets are more pronounced in a similar type of plan in the lower half of figure 19.

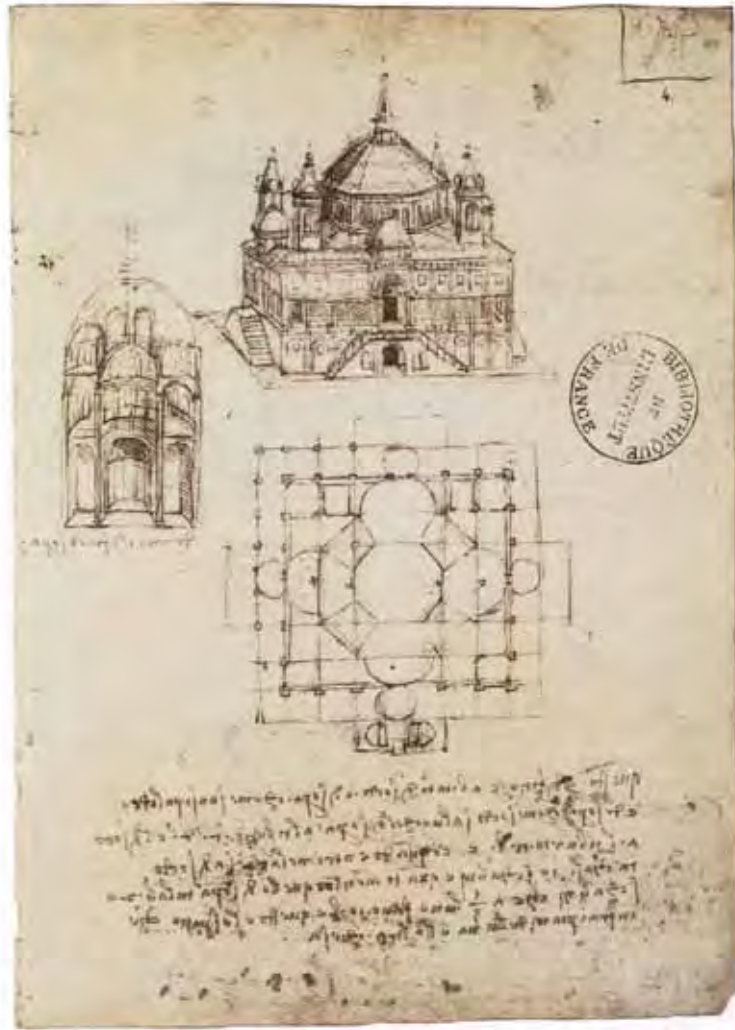


Figure 15
Leonardo da Vinci, plan and elevation of a domed Greek-cross plan church
with alternating chapels and bell towers, pen, ink and black chalk, Bibliothèque de
l'Institut de France, Ashburnham 2037, folio 4 recto (source: Chierici 1956: 235).

Notwithstanding the variations in planning and patterning, the basic themes of Leonardo's designs are reasonably simple. Plans are incorporated in a square set in a circle, set in a Greek cross, or a circle set in intersecting squares forming an octagon. His proposed churches include some on two levels, with a lower crypt, a central hall, and an upper dome. In his designs the multiplication of domes, half-domes, turrets and towers, apses, niches and the complex patterning of the walls in which all surfaces are covered with excrescences recall the Italo-Byzantine churches of Padua and the Veneto and San Vitale at Ravenna. Fricelli (1993: 510) even suggests references to Byzantine churches of Russia and mosques in Turkey. In a sense these various sacred buildings represent a summary of past architectural accomplishments.

Leonardo's evolving sketches of various types of churches narrates his search for an understanding of the limits of the possible of specific structural forms. In a visual manner Leonardo eloquently celebrates architecture by filling sheet after sheet with sketches which, in serial form, seem to become arguments leading to the most convincing conclusion to specific formal, iconic and structural types. In this serialisation Leonardo reveals his preoccupation with mutability: that his *disegno* skills enabled him to transmute the pattern of one basic form into a series of more diverse forms.

It is certainly true that “only trivialities permit but one interpretation.”²² Since Leonardo most probably did not design the domed structures for any specific setting, the Kim Veltman (1986: 139-40) postulates that he availed himself in systematic play in designing ground plans for churches, evolving in complexity by an additive method and arriving at new shapes.

By definition play happens within accepted rules, which allows for the freedom of imagination, but not unlimited fantasy. In his imaginative play with domed church plans Leonardo follows Bramante’s design for St. Peter’s Basilica, Rome, an essentially a quincuncial plan that can be defined as a cross-in-a-square plan in which the central and four angular ones are domed to form a quincunx pattern. Since Leonardo’s imaginative play with this basic church form was not intended for any practical purpose, his sketches are manifestations of a series of thought experiments.

Fricelli (1993: 510) furthermore suggests that Leonardo “may have been experimenting, as he did with so much else, with the problem of uniting the material and the spiritual by the integration of ‘perfect’ geometric forms, the circle and the square”. These forms are clearly recognizable in many of his designs. They have had, since time immemorial, the symbolic connotations of heaven and earth, to which the ideal human form is also subject. According to a medieval drawing knowledge of ideal human proportions is probably based on revived Pythagoreanism²³ of the fifteenth century in which Nicolaus Copernicus (1473-1543) and Galileo Galilei (1564-1642) were deeply immersed. These astronomers applied direct observation and, most importantly, mathematics to reveal the structure of our solar system. Galileo (1957: 295) expressed his scientific credo as follows: “Philosophy is written in that vast book that stands forever open before our eyes; but cannot be read until we have learnt the language and become familiar with the characters in which it is written. It is written in mathematical language and the letters are triangles, circles and other geometrical figures, without which means it is humanly impossible to comprehend a single word.”

Leonardo was equally inspired by the forms that Galileo later mentions, especially in his designs for cruciform churches in which geometric forms are the basis of structure as well as symbolic meaning. He may also have been influenced by Francesco di Giorgio Martini (1439-1507) who worked as an architect and engineer in Urbino, since Leonardo possessed one of his architectural manuscripts, *Trattati di architettura ingegneria e arte militari*.²⁴ Indeed, Leonardo’s sketch of a longitudinally planned church resembles that by Francesco (figure 14).

The idea that beauty is a quantifiable phenomenon derives from Vitruvius, and his illustration of the well-known “Vitruvian Man”, inscribed into a circle and a square “seems to encapsulate the belief, deeply attractive to the Renaissance, that both man and the cosmos were structured according to regular geometry”.²⁵ This idea must have appealed to Leonardo since it combined geometry with a living form. Likewise, Leonardo’s domed churches unite heaven and earth in a geometric formula. The circles and squares he applied to his compositions metaphorically represent the realms of God and human beings. In this he follows the lead of other Italian designers of churches, most notably the Church of Santa Maria della Consolazione at Todi by Cola da Caprarola (1494-1507), built after 1508, with Baldassare Perruzzi (1481-1537) as advisor (figure 16).



Figure 16
Cola da Caprarola and Baldassare Perruzzi,
Santa Maria della Consolazione, Todi, after 1508 (source: internet).

Leonardo's most renowned designs of centralised domed churches on an octagonal plan

Leonardo's most renowned design is of an octagonal domed church with side chapels (figure 17), seemingly following the design pattern of the threefold *Concatenation* corresponding to the summit or dome, the middle of the interior, and the crypt below. It is postulated that its integrated knotted design concept may also be recognised in Leonardo's architectural sketches of centralized domed churches with integrated secondary domed chapels. They echo the *Concatenation's* circular, rotating form with a static centre whose "pattern can be seen as circles around a centre" (Zwijnenberg 1999: 183). Similarly, Leonardo's domed churches have circular, rotating forms with static centres. The centralization of various of his church designs enhances the manner in which the parts, such as the dome and side chapels, interact dynamically in structural support of each other, furthermore suggesting a cosmic orientation by anchoring the plan in the four directions of a square.

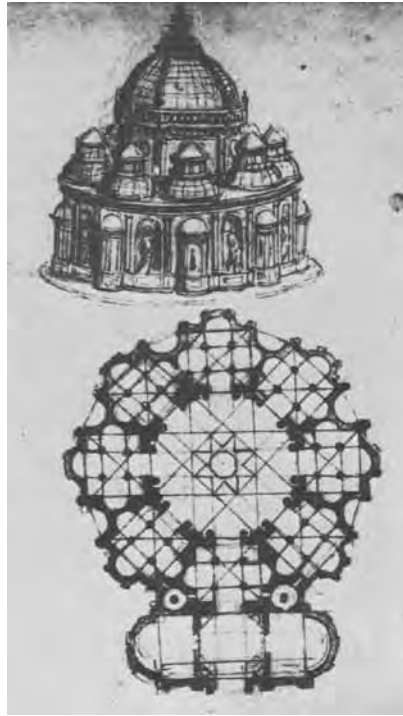


Figure 17
Leonardo da Vinci, plan and elevation of a domed church based on an octagonal central space with eight side chapels, circa 1488, 14x19 cm, pen, ink and black chalk, Bibliothèque de l'Institut de France, Ashburnham 2037, folio 5 verso (source: Chierici 1956: 234).

Most striking is the resemblance between Leonardo's ball bearing ring and the octagonal plans of centralised domed churches (figure 18). In a sheet of sketches with plans and elevations the octagonal ring marking the centres of the surrounding chapels in the upper right hand corner is clearly reminiscent of the ball-bearing race with eight sections and the plan of the domed octagonal church in figure 17 (figure 19). Analysing this phenomenon one may surmise that Leonardo envisaged the circle that can be drawn through the centres of the chapels as a moving ring, that serves, according to Veltman (1999: 140) "to illustrate his process of addition and multiplication of forms". The composite pattern of central hall and side chapels could be extended with further surrounding rings at decreasing distances linking decreasing chapels, but that would, however, render the architecture unfunctional.

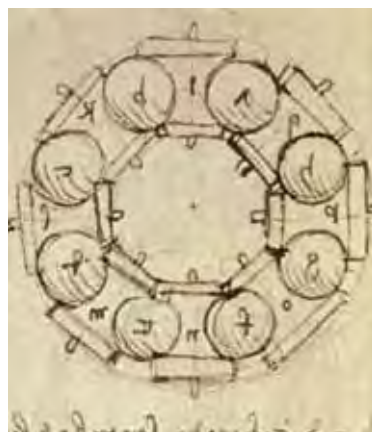


Figure 18
Leonardo da Vinci, design for a ball-bearing race, Codex Madrid, folio 20 verso (source: Reti 1974: 286).

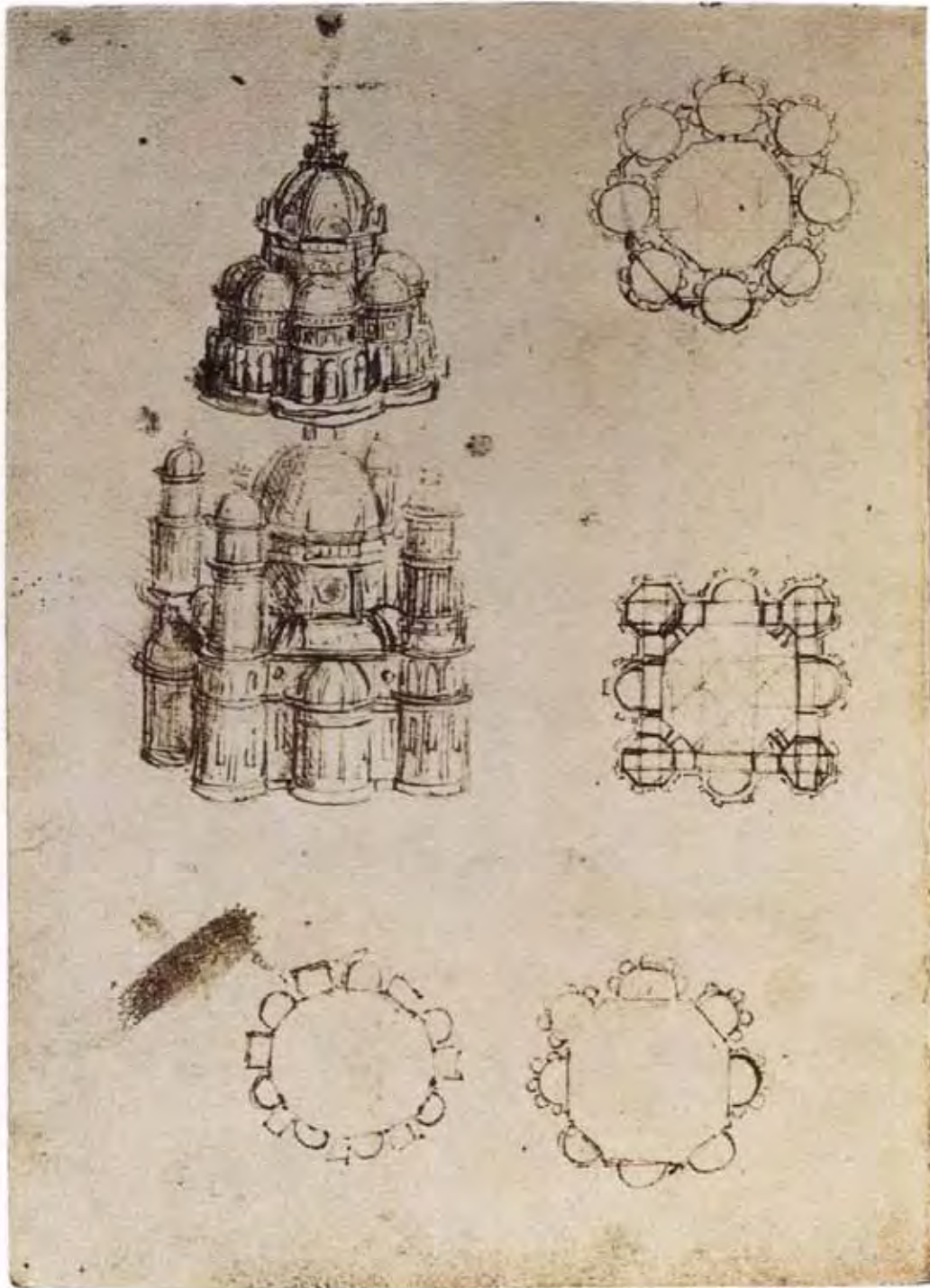


Figure 19
Leonardo da Vinci, sketches of plans and elevations of domed churches with octagonal central spaces, respectively with eight surrounding domed side chapels and four domed chapels and four corner minarets, pen, ink and black chalk, manuscript B, folio 25, verso (source: Chierici 1956: 235).

The plans of the surrounding chapels and their small domes in figures 17 and 19 are clearly similar to that of the main hall and its large dome, a pattern that approximated a fractal design.²⁶ This is the most outstanding of Leonardo's designs with the design of the octagonal main hall and side chapels following a repetitive, approximate self-similar pattern on a different scale. One may surmise that Leonardo had this idea of a growth pattern in mind. Thus the pattern

of the domed church with its exact geometrical layout may be extended from the core to the periphery, like the branching of the schematic tree which he sketched (figure 20). These unique designs are the culmination of an idea that a building is a “live” structure and that live structures follows a geometric growth pattern. Thus, in principle, the chapels may generate another series of smaller chapels, if that could in any sense be functional. However, Leonardo actually ventured to experiment with a designs of domed churches on an octagonal plan surrounded by eight domed chapels extended by eight more smaller domed spaces (figure 21).

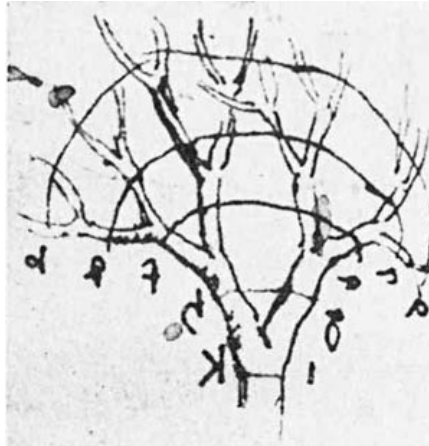


Figure 20
Leonardo da Vinci, analysis of the growth pattern of a tree, pen and ink,
 (source: <http://whattheheckisart.blogspot.com/2012/01/physorg-more-than-500-years-ago.html>).

The same fractal-like pattern can be observed in the plan and elevation of the church in the upper section of figure 19.



Figure 21
Leonardo da Vinci, sketches of plans and elevations of a domed church with the central space and eight domed side chapels based on an octagonal pattern extended by eight smaller domes, pen, ink and black chalk, manuscript B, folio 18 recto
 (source: Chierici 1956: 236).

Leonardo’s influence

Leonardo’s treatment of domed and other structures may have influenced later writers on architecture, most notably Sebastiano Serlio (1475-1554). His architectural drawings, together with those of Francesco di Giorgio Martini and Giuliano Sangallo (1443-1516), are among the earliest known, since no drawings exist of this early date by Bramante, who worked in Milan

as court architect together with Leonardo for nineteen years. Leonardo's drawings are therefore crucial in illustrating the evolution of High Renaissance and even the Baroque architecture.

It may be said that Leonardo seldom aimed at the real; his imagination most often roamed in the realms of pure invention. Proof for this statement is that, if built, this church with a high dome as central compositional element, ringed by eight smaller domes all set on drums upon a square base, would have been of enormous size. The piers that would have been needed to support the superstructure would have completely invaded the space below the dome. This kind of structural problem became real for Bramante when he constructed the piers of the new St. Peter's Basilica, Rome. His Greek cross design is reminiscent of plans proposed by Leonardo for a cruciform church with a central domed crossing (figure 14), as well as his plan (figure 21) that shows the repetition of smaller Greek-cross-shaped chapels around a central space at the crossing of a large, domed Greek-cross plan. Also Bramante's monastic church of Santa Maria della Pace, Rome, reveals Leonardo's influence. However, Leonardo had not set goal to construct any of his designs. According to Fricelli (1993: 509) Leonardo had an "immense, if concealed influence". It is suggested that Bramante was aware of Leonardo's architectural thinking and copied his *Il Tempietto* in Rome (figure 22) from his centralised church designs.²⁷ Raffaello Sanzio, not only a painter but also a renowned architect, placed a centralised church, inspired by Leonardo and Bramante, in the background of his *Marriage of the Virgin* (figure 23). The greatest homage of all is paid to Leonardo by Andrea Palladio in his *Villa La Rotonda*, Vicenza (figure 24).



Figure 22
Donato Bramante, San Pietro in Montorio, called Il Tempietto, Rome, circa 1502
(source: http://www.wikipedia.org/wiki/San_Pietro_in_Montorio).



Figure 23
Raffaello Sanzio, *Marriage of the Virgin*, 1504, oil on roundheaded panel, 170x118 cm, Pinacoteca di Brera, Milan
(source: http://www.wikipedia/wiki/The_Marriage_of_the_Virgin_Raphael).



Figure 24
Andrea Palladio, Villa Almerico Capra, called La Rotonda, Vicenza, built 1566-7, completed in 1591 (photograph: the author).

Leonardo's approach to design was to set himself problems and as Klein (210: 222) succinctly remarks, he demonstrated with his creative combinations "how far a person can take research that has no set goal". Leonardo's thought experiments with architectural plans enhanced his ability to mutate living forms into design forms such as machines and buildings.

The influence of Leonardo's anatomical studies on his architectural designs

The way in which Leonardo composed a building is comparable to the way in which he analysed human and animal anatomy because he saw analogy in the forms of nature and the artefacts he designed. Peter Murray (1969: 109) points out that Leonardo's scientific approach to anatomy has its counterpart in his numerous architectural drawings, in that he evolved different stages of planning and formal analysis, analogous to the way in which his anatomical diagrams are based on different stages of dissection (figure 25). As discussed above, Leonardo method of design was to take a number of centrally planned forms and evolve more and more complex elevations from the first simple shape. In these architectural sketches Leonardo seems to be seeking for an optimal solution to whatever form or structure he enquired into. In this search one may recognise a dialectic between various modes of being or manifestations, such as architecture and anatomy, matter and form, and oneness and multiplicity of form.

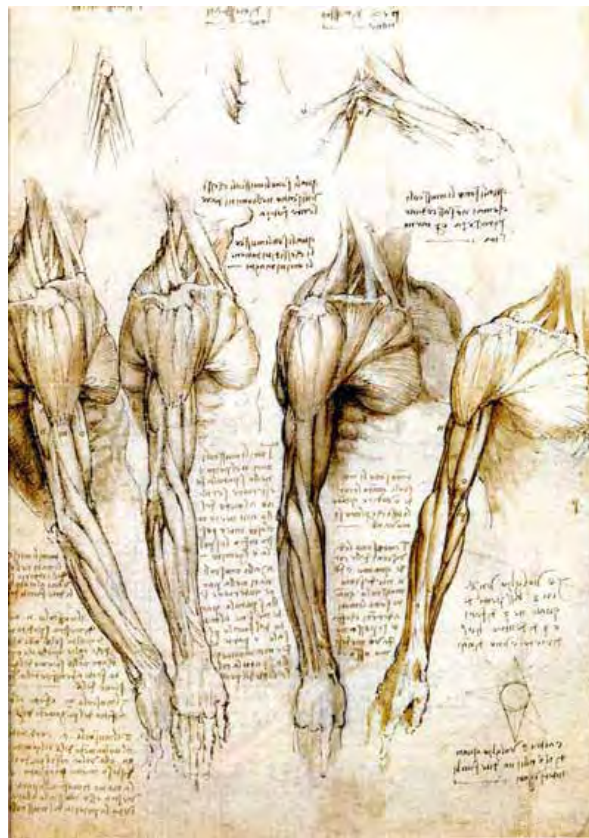


Figure 25
Leonardo da Vinci, muscles of the right shoulder and arm, 1510. pen and ink,
Royal Library, Windsor Castle
(source: <http://www.italian-renaissance-art.com/leonardo-drawings.html>).

Even more important is the fact that Leonardo did not consider the terms “mechanical” and “organic” as opposites, as Mary Garrard (2010: 143) explains:

[F]or Leonardo [these terms] were intimately linked. When he analyzed the movements of animals as “mechanical”, he meant that they exemplify dynamic motion – of organically moving parts, not metal robots. He analyzed buildings as if they were functioning machines: as Paolo Galluzzi put it, “not merely static structures based on precise proportions, but living organisms in dynamic equilibrium.”²⁸ [...] Brunelleschi's breakthrough had been to mechanize the organic, but Leonardo's contribution was to organize the tectonic.

Like living bodies or organisms, Leonardo's projected domed forms have a life of their own; like the human body.²⁹ His architectural designs approximate coherent microcosms, an idea summarised by Jonathan Jones (2010: 146): "In all his scientific work Leonardo remained loyal to the medieval idea of microcosm and macrocosm. In this traditional view of the cosmos, everything is a token of everything else: the same elements that compose a human being, compose a tree, and unexpected analogies can be discerned by the knowledgeable mind in things apparently quite different from one another."

Unexpected analogies can be found between knots, anatomy and architecture in Leonardo's oeuvre. His anatomical studies and architectural sketches, as well as the proportions of the human body and that of a building have the same quality of mutability. His creativity flourished by forging perceptual connections between design disciplines and natural phenomena.

Leonardo's classical and anti-classical, sacred and secular designs

In Leonardo's designs of architectural structures, both in his sketchbooks and in his paintings, he consistently subjected architectural mass to geometric form. He employed the classical orders as defined by Alberti and others, but not in a classical way. He never placed the orders as structural elements in a classical way between regulated intervals, but in an ambiguous way against walls, thus complicating both the orders and the walls.

Fricelli (1993: 511) also notes that a separation can be made between Leonardo's secular and sacred architectural designs: "His imagination tended toward the practical and the utilitarian in matters secular, and toward the theoretical and speculative in matters sacred." However, one may argue that the "theoretical and speculative" remained in the realm of the secular, since Leonardo's interest in architecture remained that of an engineer whose main interest in church architecture was not liturgy, but the mechanics involved in construction, referring also to natural forms. In all his researches Leonardo seems to have oscillated between practical empiricism and the alternative visual world of his imagination. He projected the latter in metaphors of cosmic correspondence, of which the *Concatenation* is an example. Even though the plans of Leonardo's centralised churches are imaginary he nevertheless evoked his world view in an architectural vocabulary that echoes Aristotelian cosmology. In this sense these designs were apt metaphors for the world view of the Roman Catholic Church. However, it should be postulated that Leonardo's knowledge of perspective – with its implicit postulate of infinity – meant that he did not subscribe to the closed cosmos in scientific terms.³⁰

Rhetorical qualities of Leonardo's architectural designs

Leonardo's exploratory manner as expressed by means of his *Concatenation* design and architectural sketches have the quality of visual rhetoric – that is a mental way of seeking or devising a "vocabulary" and "syntax" with which to envision possible forms and structures. This exploratory attitude, of searching for originality, is referred to as *innovatio* in classical rhetoric. The preparatory stage of an orator's speech is inventiveness that is necessary to ensure a convincing speech or end product. Architecture, however, is a visually expressive medium and a building's rhetorical qualities can be found in the way its diverse parts are articulated and synthesized into a totality. The architect skilled in Classical rhetoric – of which Leonardo was certainly aware – composes visually to achieve the effect of *energeia*³¹ that implies unique and purposive form, as found in his church designs. This ideal calls to mind Plotinus's assertion in *On Beauty* (*Ennead* 1, 6): "Only a compound can be beautiful, never anything devoid of

parts; and only a whole; the several parts will have beauty, not in themselves, but only working together to give a comely total.”

One may draw an analogy with Leonardo’s imaginary buildings by comparing the writing of history and fiction. History writing should be true in the sense that whatever is described actually happened, while fiction implies an author’s freedom to use literary devices to persuade the reader to take the imaginary world in which fictitious events occur seriously. His scientific enquiry into anatomy by means of dissection was expressed in precise terms in anatomical drawings, while his architectural sketches of churches may be interpreted as works of fiction in which he expresses their mediating function between human beings and an infinite cosmos that – in his era – could only be symbolically understood.

Coda

A thirteenth-century mystic, Jalaluddin Rumi, once wrote:

We are addicted to subtle discussions;
we’re very fond of solving problems.
So that we may tie knots and then undo them,
we constantly make rules for posing the difficulty
and for answering the questions it raises.³²

How else can one interpret Leonardo’s architectural endeavours – indeed all of his artistic enterprise – than as the tying of knots, that is of the creating and solving of problems. His enquiring mind and hand skilled at *disegno* embodied his fondness of solving problems as evidenced in his logo design, the *Concatenation*. Moreover, Leonardo the creator and scientific researcher not only had a predilection for tying knots and unravelling them, but in an exemplary manner his architectural designs show their parts tied together coherently in wholes seemingly endowed with a life force, while being simultaneously functional structures integrated into an aesthetic totality.

Notes

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|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | The following scholarly works that deal with Leonardo’s architectural designs are the most notable: Baroni (1956), Chierici (1956), Pedretti (1962), Reti (1974), Kemp (1981), Pedretti (1982), Pedretti (1985), Veltman (1986), Galluzzi (1987), Zwijnenberg (1999), Zöllner (2007), Klein (2010). | 7 | This philosophical insight is borrowed from Marias (1967). |
| 2 | Leonardo, manuscript H 67r, quoted from Reti (1974: 295). | 8 | For a survey of the meaning and application of <i>disegno</i> , see (Quek 2010). |
| 3 | The theme of “the knot of body and soul” in Dante’s thought is treated by Shapiro (1998). | 9 | Quoted from Kemp (1987: 131-32). |
| 4 | Leonardo, <i>Mona Lisa</i> , 1505-14, Louvre, Paris. | 10 | Quoted from Kemp (1987: 131-32). |
| 5 | See Klein (2010: 17). | 11 | Quoted from Kemp (1987: 131-32). |
| 6 | Leonardo, <i>Atlanticus</i> 203r-a, Quoted from Reti (1974: 294). As will be argued later, Leonardo’s insight into perspective defies the postulate of a closed cosmos (see note 20). | 12 | Inventiveness (<i>invenzione</i>) resulted in added internal <i>variet</i> which Bull (1965: 250) defined as a component of spontaneity that Vasari understood “enables the artist to enhance his works by adding innumerable inventive details, and, as it were, a pervasive beauty to what is merely artistically correct”. |
| | | 13 | Phillips and Priwer (2012). |

- 14 A Swiss scientist, D.F. Stüssi, calculated that Leonardo's design was technically feasible and constructed the model housed in the National Museum of Science and Technology in Milan.
- 15 It may be postulated that Leonardo prefigured some enigmatic architectural ambiguities in Mannerist paintings, such as the dangerously twisting dysfunctional flight of stairs going nowhere in Giacomo Pontormo's (1494-1557) *Joseph in Egypt*, 1518, 44x49 cm, National Gallery, London.
- 16 Leonardo da Vinci, *Last Supper*, 1495-97, refectory of San Ambrogio, Milan.
- 17 There is evidence of Leonardo's association with Bramante (Pedretti 1973).\
- 18 Quoted from Kemp (1981: 107).
- 19 See the sheet illustrating civic buildings in Codex Atlanticus, folio 395 *recto*-b. See also Guillaume (1974).
- 20 Leonardo illustrated his skill in designing double staircases with square plans (Manuscript B, folio 68 *verso*, and Manuscript B, folio 47 *recto*) and also a double spiral staircase on a circular plan (Manuscript B, folio 69 *recto*).
- 21 Tanaka (1992: 85).
- 22 Quoted from Neugebauer (1954: 2).
- 23 Pythagoras of Samos (c. 570-c. 495 BCE) was an Ionian Greek philosopher and mathematician. There is little reliable information about him since his life and works were only recorded centuries after his death.
- 24 See <http://www.omifacsimiles.com/brochures/francesco.html>.
- 25 Quoted from Rogers (2010), who acknowledged Wittkower (1962) as the exponent of this idea.
- 26 The word "fractal" was coined in 1975 by Benoit Mandelbrot (died 1910), a Polish-born mathematician. Fractals are geometrical objects that are self-similar when the distance at which they are viewed is changed. The only reference found referring to "Leonardo's fractal designs" was accessed on 2012/02/02 at <http://classes.yale.edu/fractals/panorama/Architecture/DaVinci>. The author's name is not mentioned. His brief text reads: "Why did Leonardo propose fractal designs? Perhaps because his careful drawings of flowers and water vortices made him aware of repetition across scales in nature."
- 27 Pedretti (1973: 227) states that Leonardo's "possible participation in the conception of Bramante's *Tempietto*, or even that of the new S. Peter's, must remain conjectural".
- 28 Galluzzi (1987: 101).
- 29 Kemp (1981: 117-8) quotes Leonardo's insight into man as a "lesser world" or microcosm: "By the ancients man was termed a lesser world and certainly the use of the name is well bestowed, because, in that man is composed of water, earth, air and fire, his body is an analogue for the world...".
- 30 The discovery of perspective in the Renaissance is an important aspect of the demise of the finite, closed, Medieval, Aristotelian cosmos. Euclidian space is infinite clearly seen in the "parallel postulate": given any straight line and any point not on that line, there is precisely one straight line through the point and parallel to the given line – i.e., continuously equidistant from, never meeting the given line. The conclusion may be drawn that the relationships between three disparate systems – infinite, three-dimensional Euclidian space, a finite flat physical surface, and human vision – are discovered and bound together as representation.
- 31 The term *energeia* is derived from Aristotle's *Poetics*, iii. 111.1-2.
- 32 Quoted from Helminski (1990: 204).

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Estelle Alma Maré holds the position of Professor Extraordinaire in the Department of Architecture, Tshwane University of Technology, Pretoria, and is the present editor of the *SAJAH*.